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DEFECTS FOUND IN DRAFTED MEN[1]

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I. Statement of the Problem

THE ideal population of any country is one in which all the inhabitants are physically sound, mentally competent and temperamentally controlled. Actually, the condition of any population comes far from meeting the ideal. Witness the army of doctors, the cities of hospitals, the thousands of court-houses, jails and penitentiaries. Those persons who come to the notice of such physicians and such institutions are more or less sporadically or even accidentally brought to notice. Any survey of the physical, mental and temperamental health of a large section of the population taken without selection had until recently not been made. A complete survey of the defects in the American population which would give information would be of importance for many interests. Such knowledge would be important from the standpoint of social and industrial life, since it would give some insight into the suitability of the population for the various occupations which our social organization requires.

[1] This study is based on data recorded on Form 1010 of the office of the Provost Marshal's General and Surgeon General of the Army. Acknowledgments are made to Colonel James Easby-Smith, Colonel Frank H. Wigmore and Colonel Frank R. Keefer, of the Provost Marshal General's Office. The statistics were prepared in the Section of Medical Records, Medical Department, U. S. Army, compiled under the direction of the Surgeon General, M. W. Ireland, and published with his permission. This paper is extracted from the Introduction of a larger work which is to appear shortly under the same title as a Congressional document.

It would have social-medical bearings, since it would indicate the physical and mental status of our population in different parts of the country, amid different sanitary conditions and with varying opportunities for medical and surgical treatment. It would have important military bearings since it would indicate the proportion of men available for military service of various kinds. It would have social-therapeutic bearings, since it would indicate the size and nature of the task before those who would seek to improve, by better conditions, the physical and mental standings of our population. Finally, it would have a biological and eugenical significance in so far as it would reveal the inherent failures in man to make complete adaptation to the rapidly advancing requirements of a highly artificial civilization, the constitutional limitations of the various races to meet the conditions imposed by that civilization, and the influence of military selection on the breeding stock of the next generation.

II. Method

The emergency of a great war, however, made necessary the drafting of 3,000,000 men. This included all kinds of men outside of institutions between the ages of eighteen and thirty years. Military necessity demanded that careful physical and mental examination be made of these men in order to eliminate those who would not be fit for the severe service which they would be called upon to perform. The examination was made by physicians in thousands of local boards and dozens of camps for a period of over one year. Each man was examined by one physician and in many cases by from four to twelve. These physicians were often specialists and each rendered a verdict upon the man's physical condition, and, in case a significant blemish was found, whether important enough to prevent acceptance or not, diagnosis of the defect was recorded upon the physical examination form carried by the recruit. The records thus made were sent to the office of the Surgeon General of the Army, copied upon statistical cards, and counted and tabulated. They form the basis of the present study.

The total number of men involved in the present study was about 2,500,000. Of these about 500,000 were rejected by the medical examiners of the local boards, and there are 2 lots of about 1,000,000 each who were examined at mobilization camps, September, 1917, to October, 1918. This number constitutes practically all of those rejected by local boards and about two thirds of those examined by mobilization camps, but it is representative of all. A few men between the ages of eighteen and twenty-one are included, but the great majority are men between the ages of twenty-one and thirty years inclusive. The exact number of men examined to furnish these data can never be precisely known. By a method of approximation based upon statistics of the Provost Marshal General's office and those of the Surgeon General's office, a hypothetical number of 2,753,922 is arrived at, and this is used as the "strength," or total population, upon which ratios are calculated. In the present paper the unit of discussion is the rate of incidence of a particular defect in 1,000 men. The rate 1, therefore, when given as the rate for a defect, means that 1 man out of 1,000 was found with that defect. Since the total of the men is about 2,754,000, "1" means that there were 2,754 men found with the given defect. The rate "2" means that there were twice this number, *i.e.*, about 3,500, etc. In the present paper, rates will usually be given as integral numbers, except in the case of small ratios.

III. Results

It is proposed to consider in turn: first, the relative frequency of the main groups of defects found; secondly, the classification of men in relation to military service on the basis of these defects; and thirdly, the relation of the defects to geographical distribution, occupation and race.

1. *Total Defects Found*

In the total population examined there were found 468 men defective per 1,000 examined. That is to say, over half of the men were found to be without any physical or mental blemish significant enough to be recorded. In some of the men 2 or more defects were noted, so that in the total there are 557 defects noted per 1,000 men examined. The number would have been somewhat higher except for the fact that only one, the major defect, was, in the first million men, copied from the examination form and was used in the present statistics. The number 557 is important because it represents the sum of all of the ratios per 1,000 men examined for the 269 defects and groups of defects that were recognized.

Of the defects found, those of a mechanical sort, involving bones and joints, appendages, hands and feet, were commonest and constitute about 39 per cent., or about two fifths, of all defects. The second place is taken by defects of the sense organs, about 12 per cent.; next come the two great and nearly equallysized disease-groups of tuberculosis and venereal disease, which constitute together 11 per cent.; then follow the cardiovascular diseases and defects, about 10 per cent.; and those that fall into the group of defects of developmental and metabolic processes, also about 10 per cent. Of minor importance are the groups of nervous and mental defects, about 6 per cent.; diseases of the nose and throat, about 5 per cent.; those of the skin and teeth, about 3 per cent.; those of the respiratory organs (other than tuberculosis) 1 per cent.; and "others" about 3 per cent.

The defects of the mechanical group are, as stated, far and away the commonest defects found in examination for military service and they constitute the most important group from the military point of view. As stated, the group includes about two fifths of all defects and 218 out of every 1,000 men examined showed some important defect belonging to this group. Numerically the most important item in this group, and indeed in the whole list of defects found in young men, is that of weak feet, including various forms. Of these, there were over 300,000 cases noted, constituting more than half of the group of mechanical defects and giving a rate of 124 per 1,000 men examined. That is, one eighth of the men examined had weak feet. As for other mechanical defects, deformed and injured appendages were found in over 50 men per 1,000, and hernia in 40 per 1,000.

Of the group of defects of the sense organs, about half were refractive errors of the eye, and one fourth were defects and diseases of the ear, including deafness.

Tuberculosis gave a rate of 30 per 1,000, constituting over 5.4 per cent. of the defects found. Venereal diseases gave a rate of 32, nearly 5.8 per cent. of the defects.

Of the developmental and metabolic defects, the most important are: weight below the standard required for military service, under-height, curvature of the spine, goiter (both simple and exophthalmic), defective chest measurement, imperfect development of the genitalia, and cleft palate and hare lip. There were 73,000 men found to be below the military standard of weight and this group constitutes about 5 per cent. of the defects found.

Of the nervous and mental defects, mental deficiency was the most important. It was recorded by medical examiners in nearly 40,000 men, but many more than this were detected in subsequent psychological examinations.

Of diseases of the nose and throat, the most important was enlargement of the tonsils, recorded in 64,000 cases.

Finally, of defects of the skin and teeth, those of the teeth constituted the most important group, including 40,000 men.

This summary of the various groups of defects found in the American population must not be passed by without a word of warning. As was stated above nearly half of the men examined showed a defect considered worthy of remark. It may well be a matter of surprise that not more defects were detected; probably this would have been the case, had the examinations been less expeditiously conducted. Many of the defects were obviously noteworthy only from a military standpoint. From the point of view of civil life, it is no defect that the South Italian is under 60 inches tall, though this constituted a defect from a military point of view. Also many of the defects noted, including most cases of venereal disease and many of the mechanical group, were not of a grade sufficient to render the man unfit for military service. A large proportion of the mechanical defects, important as they are in a man who is to be used as part of a fighting machine, are not a serious handicap in civil life. Also many of the defects of the sense organs that were found are easily capable of correction so as to fit a man to perform his duties in civil life. Altogether it is clear that fully ninety per cent. of the defects found are not of such a nature as to interfere seriously with the man's performing services of the highest order in civil life.

From the standpoint of the Army, as stated, the defects are not equally important. Recognition of this fact led to the establishment of 5 categories by draft and military officials. There was first the so-called Class Vg, the class of men who, on account of physical defects, were rejected by local boards from any military service. These men were not sent to camp. The men received at camp were placed in one of four "Groups," denominated respectively A, B, C, D. Group A includes men who were accepted for general military service. It comprised 2 groups, those in whom was found no defect, and those in whom was found only some minor defect which did not interfere with full military duty. Group B (which became operative only during the latter part of the draft period) included registrants with a defect which would permit of general military service after a cure had been effected by operation or otherwise. Group C included registrants with such defects as would permit them to function only in a special or limited military service in a special occupation or capacity, usually clerical. Finally, group D, included men rejected on physical grounds from any military service. The relation of certain major defects to grouping is shown graphically in Fig. 1. It appears from this figure that nervous and mental defects, including feeblemindedness, mental deficiency, paralysis, psychasthenia, constitutional

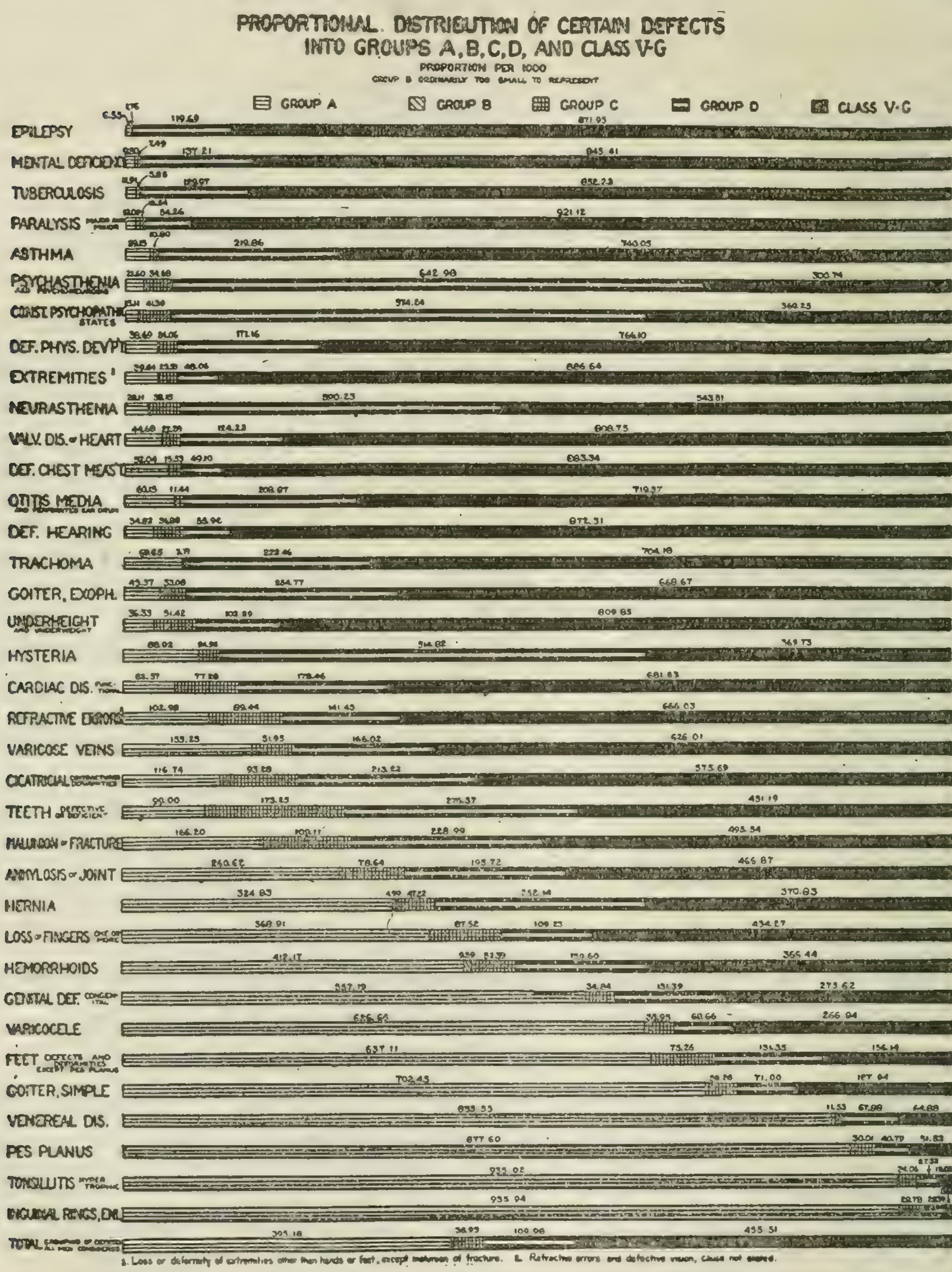


FIG. 1.

psychopathic states, and neurasthenia were among the defects, victims of which were most commonly rejected. These are the defects that are incapable of or incompatible with the strain of military training and active service. It doubtless would have been well had none of these been accepted for general military service. It is noteworthy that certain of these conditions, like psychasthenia, constitutional psychopathic states, neurasthenia and hysteria, which are difficult to detect, were passed over by local boards and were, therefore, an exceptionally common cause for rejection at mobilization camps. On the other hand, the figure shows that relatively few men were rejected for enlarged inguinal rings (incipient rupture), for enlarged tonsils, for venereal diseases, and even for flat foot. For loss of fingers, hemorrhoids (piles) and hernia (rupture) about one half were rejected and one half accepted for general military service. Among other defects which led to nearly complete rejection were otitis media (inflammation of the middle ear due to infection), valvular diseases of the heart, asthma, paralysis, and, above all, tuberculosis. Altogether about 12 per cent. of the men examined were rejected for any military service.

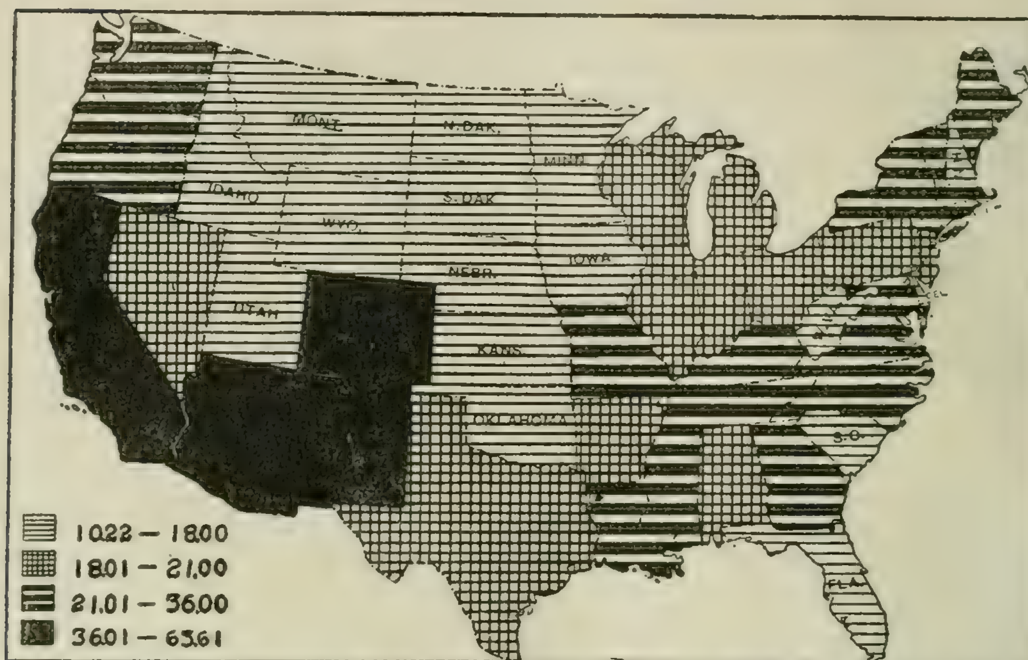
2. *Distribution of the Defects Found.*

We may now consider briefly the principal results secured concerning the geographical, occupational and racial distribution of the principal diseases and defects. The statistics for each disease have been classified by states, by sections, and by consolidated sections. A word may be said at this point about sections. It was early recognized that most of the larger states could with advantage be divided into one or more sections, depending upon geographical, occupational or racial differences. Sections having similar geographical, occupational or racial conditions were grouped in many cases and for the purpose of further study grouped or consolidated. Some of the findings of these consolidated sections are considered below toward the end of this paper.

1. *Tuberculosis.*—The facts concerning the distribution of this widespread and frequently fatal disease are shown in Fig. 2. It appears at once that the region of highest incidence of this disease is in the desert states of Arizona and New Mexico and the adjacent states of Colorado and California. The reason for this is that the described area includes so many young men who have gone there because they were already victims of active tuberculosis. Perhaps some of the tubercular men are sons of men who have migrated to these states on account of non-resistance to tuberculosis and themselves show the family diathesis. The next most infected territories are the two northernmost Pacific states, the New England states and New York, and the group of states immediately south of the Mason and Dixon

line, including also the states of Missouri, Louisiana, Mississippi and Georgia. New England has long been known as a region with a high rate of tuberculosis, a disease whose fires are fed

PULMONARY AND SUSPECTED TUBERCULOSIS



RATIO PER 1000 MEN REJECTIONS, CAMPS AND LOCAL BOARDS

Fig. 2.

by the large number of recent immigrants. The states of Virginia, North Carolina, and Kentucky contain numerous sanatoria for the tubercular. The high rate in the Gulf States is probably due to the presence in them of a large proportion of negroes, as this race, particularly the mulatto, is especially susceptible to tuberculosis. The smallest amount of tuberculosis is found in the Great Plains region and the northern part of the Rocky Mountain range. This is an area occupied largely by non-British stock, which comprises exceptionally vigorous people. Tuberculosis in the rural southern states tends to overweigh the rate of tuberculosis in the rural population of the country as a whole. But in general, the agricultural areas of the north show less tuberculosis than the urban districts.

2. *Venereal Diseases.*—These diseases have a social interest which far exceeds the military one. Their numbers give a rough index to the success that the different states have met with in their efforts to inculcate the sex mores and the capacity that the population of the different sections have in inhibiting the sex instincts. The details of distribution in different parts

of the country shown in Fig. 3 will repay careful study. This group includes syphilis, chancroid and gonococcus infections, which together give a rate of 32. This rate, or at most the rate of 56 per mille obtained from the second 1,000,000 men alone, must be taken as the most precise information we have concerning the proportion of men in the United States of the ages of eighteen to thirty, who show symptoms of venereal disease at a

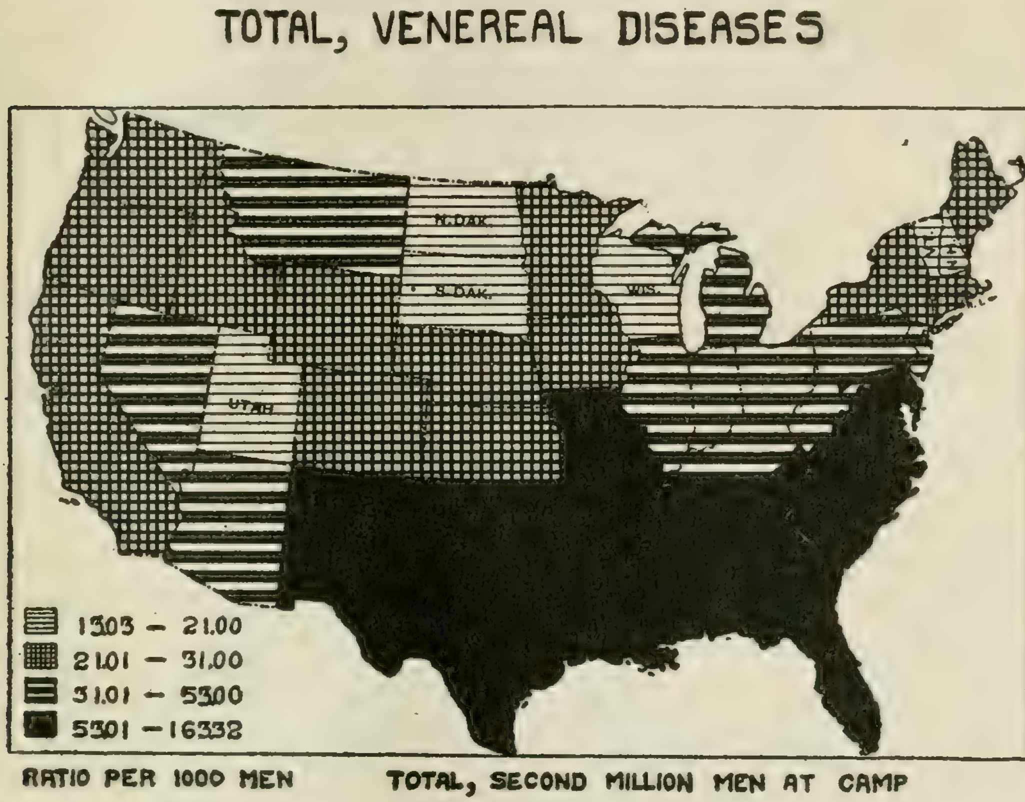


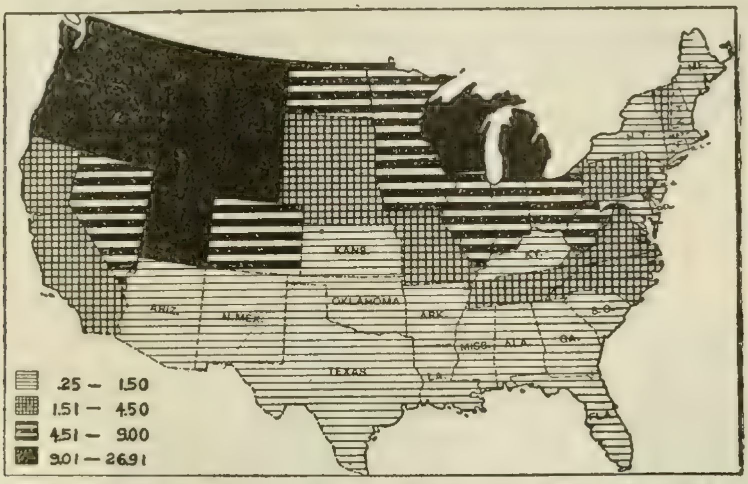
FIG. 3.

given time. There is no adequate statistical justification for the statement made by propagandists that 10 per cent., or more, of the men of the United States are affected with venereal disease. No "conservative estimate" can replace, or add anything to, the results of the exhaustive individual examination of over 2,500,000 (probably 2,754,000) men which have led to the figures just quoted. It is to be remembered, moreover, that this rate of 3, or at the maximum 5.6 per cent., includes the colored population as well as white, and there is good statistical evidence that colored men are several times as apt to be infected as white men. As the figure shows, just those states with the largest proportion of colored population have the highest ratio of venereal diseases. Adjacent regions with an intermediate proportion of colored population showed an intermediate amount. Relatively small rates were found in the New England states, including New York, and in the northern states west of the Mississippi River. Wisconsin and the Dakotas, inhabited largely by immigrants from northern Europe, especially Scandinavia, show the lowest rate for these diseases. If the rural rate is a shade higher than the urban rate, it is because the negroes of the south unduly swell the proportion of infected states. In the northern states, like Maine, Massachusetts, New Jersey and Ohio, the rural rate is less than the urban. On the other hand, the venereal disease rate for the eastern manufacturing states, and especially for the commuter sections (rate 1.9) is less than that of the northern agricultural districts; but they are not lower than the rate in those agricultural regions which contain a large proportion of recent immigrants, especially from northwestern Europe.

3. *Goiter.*—Goiter is a disease characterized by an enlargement or a misfunctioning of the thyroid gland which occupies the lower neck region. Two types of goiter are distinguished; simple goiter, characterized primarily by enlargement of the gland, and exophthalmic goiter characterized less by enlargement of the gland than by a nervous, irritable condition, by rapid heart, and by distention of the eyeballs. It was formerly regarded as rather a rare disease in America; it was thought of as a defect which belongs to mountainous regions of Europe. One of the surprises of the draft examination is that many young men, the sex which is relatively the less affected by goiter, should be so affected. There were found over 20,000 cases, giving a rate of about 8 men per 1,000. Not less surprising is the geographical distribution of simple and exophthalmic goiter. It seems that goiter is a disease preeminently of the Great Lakes basin and of the extreme northwest. Goiter is almost absent throughout the southern states from the Cape Fear River to the Colorado. This clean-cut distribution of goiter should help in the solution of its etiology. The area of its greatest incidence in the Great Lakes region nearly coincides with that of the hard waters of the Niagara limestone. But in Oregon and Washington, where the incidence reaches the maximum, the waters are soft. However, the water of the cities of the northwest comes largely from the mountains of the Cascade Range and the Rockies, and mountainous regions are those of the highest incidence of goiter in the European countries. On the other hand, the Great Lakes region is without important mountains. Consequently the presence of lime in the water or the mountain origin of drinking water can neither of them be

considered sufficient or exclusive causes of goiter. It is believed that the distribution of goiter by occupations is subordinate to the geographical distribution. It is not because the men of

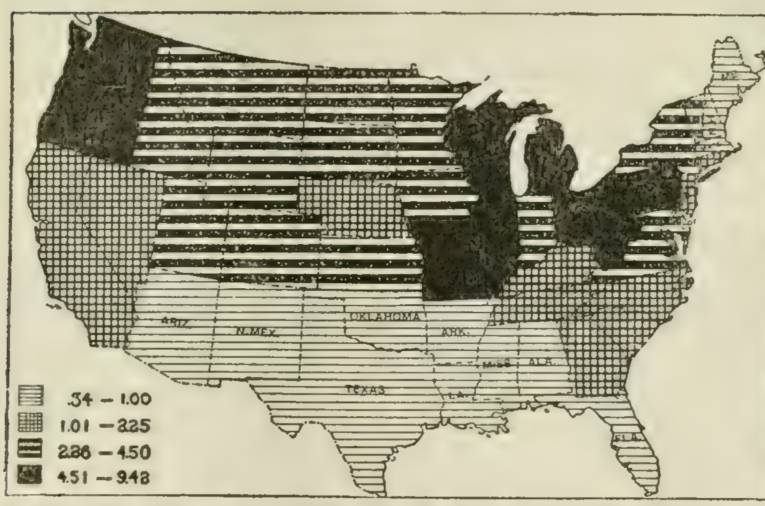
GOITRE, SIMPLE



RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 4.

GOITER, EXOPHTHALMIC



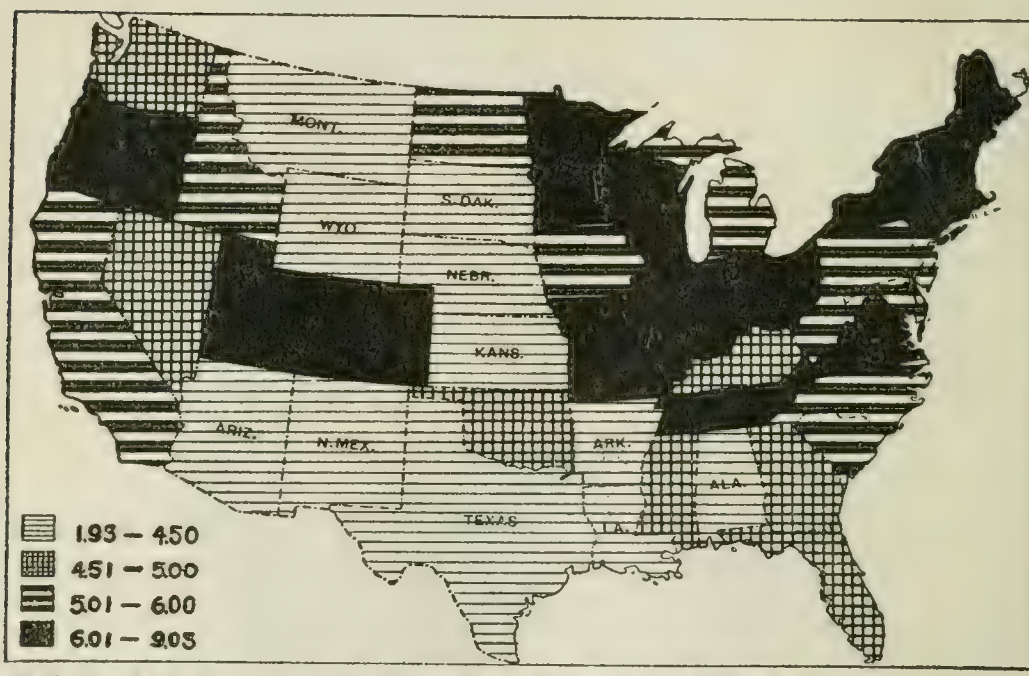
RATIO PER 1000 MEN TOTAL. CAMPS AND LOCAL BOARDS

FIG. 4*a*.

Washington are largely lumbermen that they have goiter, but it is because they live in the state of Washington. On the other hand, it is not clear that race has no significance in the occurrence of goiter. For not all persons who live in goiterous regions are affected with goiter, and it is possible that there is a selection based on race of those who show the symptoms. There is an excess of goiter among the Scandinavians and the rate is higher still in those sections with a large proportion of Finns, but it must be recognized that the sections inhabited by Finns are both in northern Michigan, a center of goiter. See Fig. 4, simple goiter, 4*a*, exophthalmic goiter.

4. *Curvature of the Spine.*—Though it can not be denied that there are hereditary factors which favor the development of spinal curvature, yet it is probable that a large proportion of the cases are developed under conditions of bad posture. However it is induced, the amount of it found was strikingly large. It occurred on the average 5.5 times in every 1,000 men examined. The map in Fig. 5 shows the distribution of curva-

CURVATURE OF SPINE



RATIO PER 1000 TOTAL, CAMPS AND LOCAL BOARDS

Fig. 5.

ture of the spine by states. It appears that New England and the densely populated states about the Great Lakes are regions of high incidence. States of the Great Plains and the Gulf show relatively little curvature of the spine. The low rate in the Gulf states is doubtless due largely to the negro population, which is one relatively little affected with curvature of the spine. In general, the great agricultural regions are less affected than the eastern manufacturing sections. There is a minimum rate in the sparsely settled sections along the Mexican border, which contain a great many Indians and Mexican-Indians. The highest rate, 7 per 1,000, is found in sections having a large proportion of French-Canadians.

5. *Defective Physical Development and Deficient Chest Measurement.*—These terms include a large range of conditions due to a variety of causes. The group is of great significance from a military standpoint, but its numbers are not very large, only about 9,700, giving a rate of about 3.6 per 1,000 men. The group has a great importance for social therapeutics since it is largely due to unhygienic methods of living, although in a considerable part it is due also to congenital defects. The distribution of these defects is shown in Figures 6, 6*a*, 6*b*. The center for defective physical development is found in the states which are grouped around Chattanooga, and it seems probable that the high rate in this territory is largely determined by the pres-

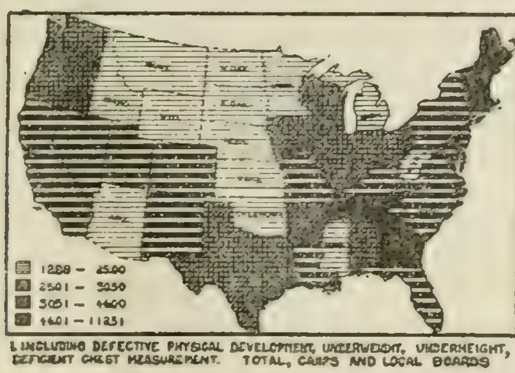


FIG. 6.

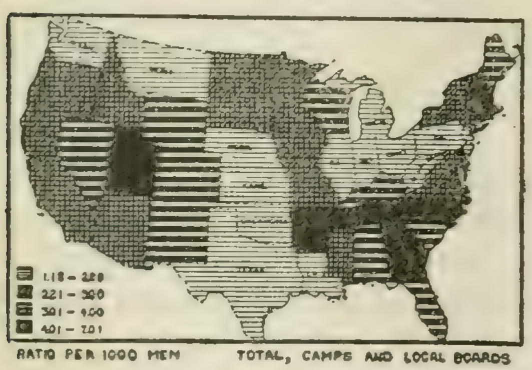


FIG. 6*a*.

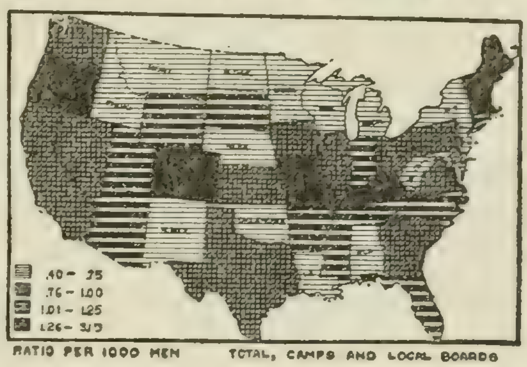


FIG. 6*b*.

ence of hookworm infection. There is another center in New England, and this seems to be controlled very largely by the French-Canadian immigrants, who show a high rate of defective physical development. There is a slight excess of defective physical development (but not of deficient chest measurement) in rural districts. This is doubtless determined by the hookworm infection among the agricultural whites of the south. In the northern states that contain large cities, there is a relatively low urban rate for "defective physical development" which

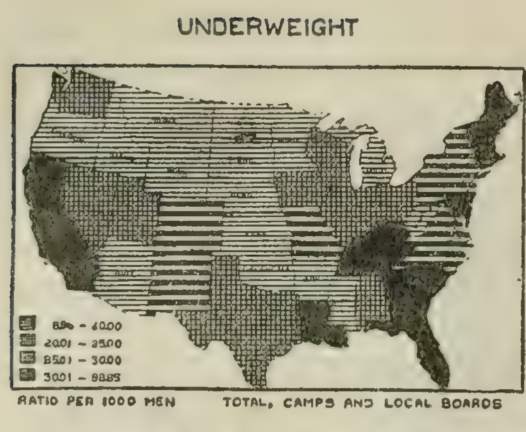


FIG. 7.

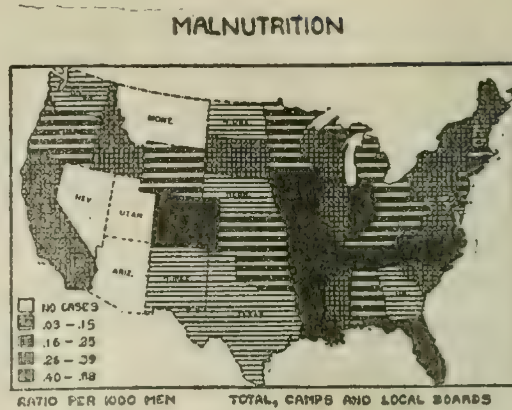


FIG. 7*a*.

may be due to an avoidance of this vague term by physical examiners. There is a relatively low urban rate for deficient chest measurement in rural districts of the north and this may be in part accounted for by the more varied muscular activity of the children who live in the open country.

6. *Underweight.*—The physical examination standards prescribed a minimum weight of 114 (or in certain cases 110) pounds. Many of the registrants, however, were rejected who weighed far more than the lower limit, when their weight was markedly below that of the normal man of their height. Underweight, consequently, included two groups, those who were racially small and those who suffered from malnutrition in the broad sense. Malnutrition was, of course, chiefly the result of parasitism; and altogether there were noted 73,000 men, giving a rate of 27 (Fig. 7*a*). The map in Fig. 7 shows the distribution of underweight in the different states. One obvious center is in New England. This is largely due to the recent immigration to that section of small races like the South Ialians, Portuguese, and Polish Jews. The second center, in the southeast, is chiefly due to hookworm and malaria. The underweight that characterizes the state of California is doubtless chiefly due to

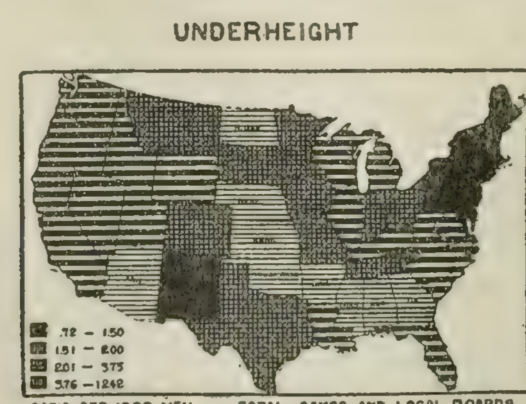


FIG. 8.

tuberculosis, but may in part be due to the presence of small races, like the Japanese. Underweight is prevailingly an urban defect, primarily because the northern cities which tend to control the statistical result are those to which the small races of South Italians and Polish Jews have largely immigrated.

7. *Underheight.*—Stature is determined primarily by racial conditions. Thus, the Scotch are the tallest people on the globe and the South Italians and Polish Jews are among the shortest people of Europe. Stature seems to be practically independent of environmental conditions and, if underheight is commoner in cities than in the country, it is not due chiefly to environmental conditions in urban districts, but to the fact that the short races prefer to live in cities, while the tall Scandinavians and Scotch are largely rural dwellers. The total amount of underheight was not as great as of underweight—only about 8,000 cases, giving a rate of 3 per 1,000 men examined. This is largely because the minimum requirement for military service was, during most of the period of the draft, retained at 60 inches, a stature a little less than the average for males of the short races that have made their home in this country. The geographical distribution of underheight is shown in Fig. 8. New England and the Middle States, the states that have received the greater part of the new immigration, show the largest proportion of presence of underheight. The rate is high on the Pacific coast also, which result may possibly be due in part to the influence of Orientals. Relatively little underheight was found in agricultural districts, especially in the south. The rate is high in the eastern manufacturing and commuter group because of the presence of short races in them. There was a rate of less than 2 in the Scandinavian sections, but a rate of over 8 in those occupied largely by French-Canadians. The condition, while not serious, is also one that can not be altered by any prophylactic measures. If there is any desire to keep down the proportion of our population who are below the stature requirement for military service, it can only be done by restricting immigration of people belonging to short races.

8. *Imperfect Sex Development.*—Of the defects of this group about 8,000 cases were found, making a rate of 3. The defects of this group, congenital in their nature, can not be altered by prophylaxis, and, though remedied by surgical operations, recur in subsequent generations by inheritance. The commonest of these defects is cryptorchidism, or failure of descent of one or both testes. The distribution of these defects is shown in Fig. 9.

This map yields the striking result that the defect predominates in the northern one or two tiers of states west of the Mississippi from Minnesota to Washington. There is also another center of incidence in southern New England. The latter is possibly due to the presence of French-Canadians, since the section in which they are most numerous have a rate for cryptorchidism of over 3. As for the states in the northwest, most of them contain considerable Scandinavian population and the Scandinavian group section also shows a rate of over 3 for cryptorchidism alone.

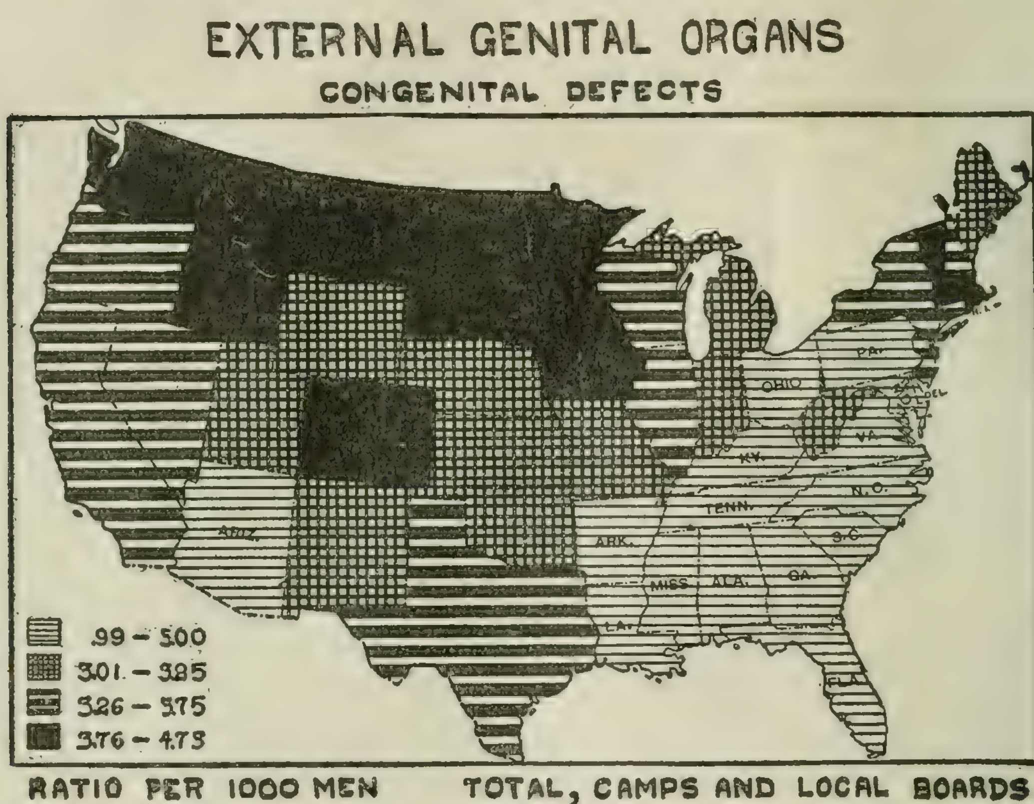


Fig. 9.

In any case, the variations in the rate are to be accounted for on racial grounds. The relatively low rate throughout the south is probably influenced by the presence of negroes, in whom cryptorchidism is relatively uncommon. (?)

9. *Deformed, Atrophied or Lost Arms.*—Serious defects in the arms were found in about 15,000 cases. The loss or deformation of the arms is not only of great military, but also of great civil importance, since it limits a man's activity in industrial life. Indeed, most of the operations of manufacturing and commerce require the use of two arms. Such a defect is entirely prohibitive of military service. The distribution of loss of upper extremities by states is shown in Fig. 10. It is seen that this is common in the states bordering on the Allegheny

Mountains from Pennsylvania to Georgia. It is also found in excessive numbers in the Gulf states from Mississippi westward, and in the state of Washington. The loss of the upper extremity is determined largely by the hazard of occupation. Probably an important reason for loss of the upper extremity along the Allegheny Mountains and in the western Gulf states is

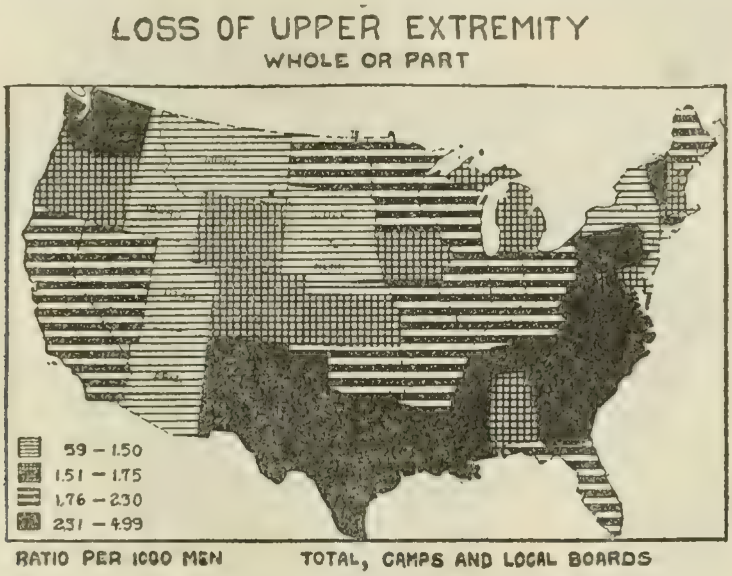


Fig. 10.

the extensive lumbering operations going on in those states, or which have gone on in them during the last ten or fifteen years. Similarly with the state of Washington, which is now the principal lumbering state of the Union. Saw-mills, planing-mills, box factories, all offer special hazards to the appendages. Also in rural communities the opportunity for the proper setting of broken bones is much less than in cities. Consequently, we find faulty union of fractures of the upper extremities relatively common in rural states. Also loss of upper extremity, deformity of upper extremity, ankylosis of joints are all much commoner in rural districts. However, the hazard of cotton mills in the south (in which there seems to have been in the past imperfect protection of workmen) is doubtless responsible for a considerable part of urban loss of arms such as is found in southern cotton mill states and their cities.

10. *Deformed, Atrophied or Lost Legs.*—This defect is 50 per cent. commoner than the preceding defect, showing that legs are more subject to hazards that maim but do not kill than arms. The map showing the distribution of loss of lower extremity, whole or in part, is given in Fig. 11. This figure shows the relatively large incidence of loss of lower extremity in the states of Washington and Utah, and in the mining states

grouped around the head of the Ohio River, and also Virginia. There is more than the average of this defect found in the states from Louisiana northwest to Colorado, while the mining states of Idaho, Wyoming and Montana have relatively little of it. It seems probable that the loss of extremity in the different states is determined in part by lumbering operations and in part by mining. At any rate, the defect is found more predomi-

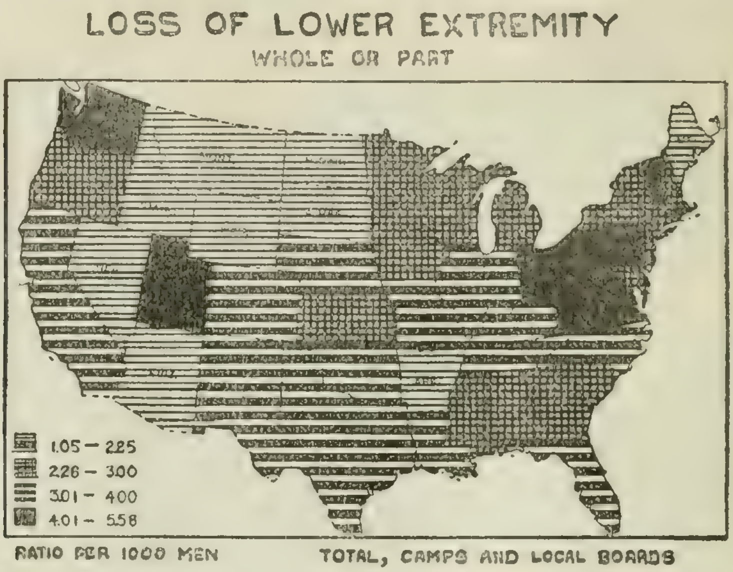


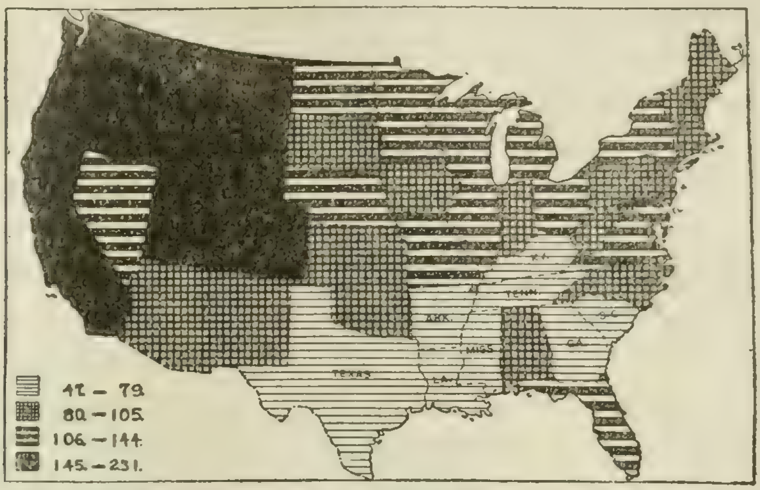
FIG. 11.

nantly in the rural regions than is loss of the upper extremity. This is probably because there is little danger to loss of lower extremity as compared with loss of upper extremity in cotton and other mills, while the hazard to the lower limbs in various agricultural pursuits is equally great to both pairs of appendages. In centers for railroad shops, like Ogden, Utah, the rate for defective legs is very high.

11. *Weak and Deformed Feet.*—As already stated, this is far and away the most important defect, numerically and from the standpoint of military service, found in drafted men. It is also of considerable economic importance in civil life, since it handicaps a man in performing duties which require standing on the feet, the very conditions which have induced it in the first place. It is to a great degree dependent upon the wearing of ill-fitting shoes and hence may be combated in the future by propaganda directed toward the reform in the shape of shoes. From the biological standpoint the important breakdown of the feet in the comparatively young male population indicates that the feet are badly adjusted to the demands made upon them in modern civilized life.

The geographical distribution of flatfoot (which controls in this group of defects) is shown in Fig. 12. The one striking fact in the geographical distribution is comparative freedom from foot defects enjoyed by the southern states. This is due both to the comparative absence of shoes in the rural population,

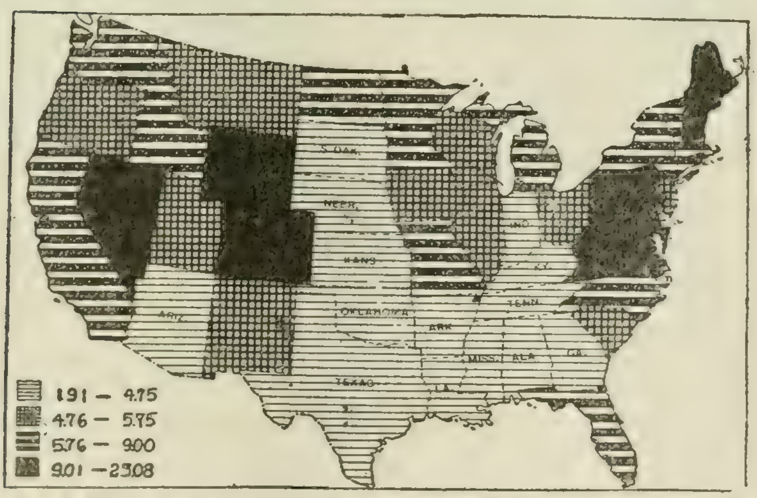
PES PLANUS
FLAT FOOT



RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

Fig. 12.

HAMMER-TOE AND HALLUX VALGUS



RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

Fig. 12*a*.

during early years of life and to the large colored population which, partly because of such freedom from shoes and partly because of anatomical and physiological peculiarities, is less affected with weak feet than whites. The great center of flatfoot is in the northwest, probably partly on account of the large body-size of immigrants into that territory. For flatfoot, among other things, is induced by the weight of the body which has to be supported. Flatfoot and particularly hammer toe and bent great toe (Fig. 12*a*) are common in the densely populated states of the northeast. This is due to the presence in those states of large cities, for bad feet are above all defects of the cities, due to the conditions of life, which make it necessary to stand on the feet, to walk on hard pavements and to perform less varied occupations than the country man is expected to do. Especially in the North there is a more constant use of shoes during the earlier years of life, and of deforming and ill-fitting shoes at all times of life. The racial difference in respect to flatfoot is not striking. It is especially common among the larger races, like the Germans, Austrians, and Scandinavians.

12. *Deformity of Hand or Loss of Fingers.*—Although less important from a military point of view than weak or deformed feet, deformed or absent hand or fingers are of great importance in social life, particularly in the various industries. There were over 20,000 cases of this defect recorded, which means that nearly 8 out of every 1,000 men are defective in this respect. There are 3 principal regions of incidence: first, the New England states; second, the group around the Great Lakes; and third, the group in the northwest. As the defect is much commoner in rural than in urban districts, those states which contain great cities like New York, New Jersey, and Illinois fall below the upper third of states arranged in order of incidence. The defect mentioned is associated in part with the lumbering industry and its associated saw-mills. This is no doubt why the rate reaches a maximum in the state of Washington and why it is very high in Maine, Michigan and Wisconsin. Also it is quite clear that mining operatons are contributory and hence we find a relatively high rate in the states of Montana, Idaho, Wyoming, West Virginia, Ohio and Michigan. The rate in Pennsylvania is kept low by the presence of large cities. The region of the great southwest with treeless plains and deserts is relatively devoid of injury to or deformation of hands. The rate for finger defects is high among the Finns, but that is largely because they are engaged in mining. It is relatively low in the agricultural sections, particularly those made up of native stock.

13. *Hernia.*—The inability of the lower abdominal muscles and fascia to withstand extraordinary strain is an indication of man's imperfect adaptation to the erect position and to the demands made upon him by the severe physical strains of modern civilization. The presence of threatened or frank hernia is one of the greatest defects found in men of military age. It was detected in nearly 40 per 1,000 or 4 per cent. of them, a total of over 100,000 individuals.

The distribution of hernia and enlarged inguinal rings over the United States is shown in Fig. 13. One of the striking facts represented on this map is the great uniformity in the distribution of hernia in the different states. The range is small, varying from a maximum of 29 in Florida to a minimum of 13 in Maryland. Consequently the variations in incidence as shown on the map are apt to be influenced by such incidental matters as idiosyncrasies of examiners at the various camps. Taking the chart as it stands, it appears that there is a high rate for hernia in the Rocky Mountain states, Great Basin and the Pacific slope. Men from these states were all examined at

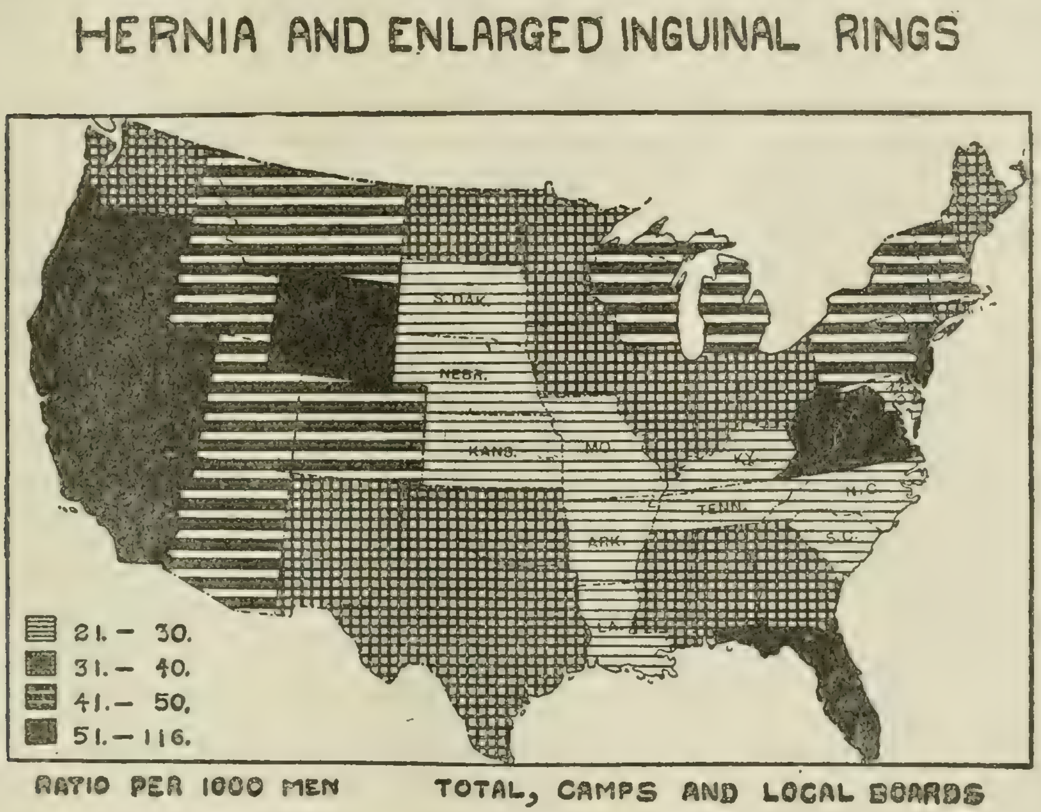


Fig. 13.

Camp Lewis. On the other hand, these are largely mining states where, there is reason to suspect, the men of military age have been subjected to an unusual amount of heavy work. Similarly, we find that the rate is high in Pennsylvania and West Virginia, mining states; also in most of the New England states, Michigan and Wisconsin. Among the different races considered we find the highest rate among the French-Canadians, Germans, and Austrians, and the lowest rate among recruits of Scotch origin.

(*To be Concluded*)

THE HAVEN OF HEALTH

By GEORGE ERIC SIMPSON

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THOMAS COGAN, physician and schoolmaster of Manchester, in 1584 published a book to which he gave the modest title "The Haven of Health." At the time of the publication Queen Elizabeth had been on the throne twenty-six years. Four years later the Spanish Armada was to be ingloriously swept from the seas by a combination of British valor and unfriendly winds. Three years were still to pass before William Shakespeare would move to London. The jubilee of learning was soon to be at its full height.

Galen was still the god of biological science, whom to question was blasphemy. At this time, as for the previous fourteen centuries, his writings were considered the last word in all discussions physiological or anatomical. None might question his authority without encountering the opposition of all God-fearing folk. There had come from the pen of Vesalius some forty years previous to the writing of the "Haven" a work of anatomy, the "Fabrica Humani Corporis," which was a worthy harbinger of the new learning. Vesalius had arrived at the peculiar conclusion, probably not without many misgivings, that more might be learned by direct observation than by poring over the works of the philosophers of Greece and Rome. But even so strong-minded and purposeful man as Vesalius found it sometimes expedient to tread with meticulous discretion so that his differences with Galen should be passed over lightly, as, for example, when he was content to wonder at the power of Almighty God who was able to cause the forcing of the blood from the right to the left ventricle through the invisible pores in the thick wall separating these two cavities. But the two-score years must still pass before Harvey, in 1628, should bring out his book demonstrating the proofs of the circulation of the blood. Harvey followed in the footsteps of Vesalius in that his knowledge was gained by direct observation rather than by minute and painstaking perusal of the authorities.

The "Haven of Health" was first published in 1584 or 1586. There was a second edition, "corrected and augmented," in

1589, followed by others in 1596, 1605 and 1636. The last edition was merely a reprint of the first. The copy of Cogan's book to which the present writer has access was "Imprinted at London by Richard Field for Bonham Norton, 1596." The dedication to the "Right Honorable and my verie good Lord, Sir Edward Seymour Knight, Baron Beauchamp, and Earle of Hertford" bears the date 1588.

Cogan tended to break away from precedent by writing in English. As early as 1534 to be sure, Sir Thomas Elyot had brought out a semi-scientific book, "The Castell of Helth," in the vernacular. But so much feeling was aroused in medical circles by Elyot's presumption that it was found necessary in the preface of the later editions to set forth a defence of the innovation:

> Now when I first wrote this boke I was not all ignorant in physicke. And although I have never been at Mountpelier, Padua, nor Salern, yet have I found some thyng in physicke whereby I have taken no little profit concerning myne owne helth. . . . But if physicions be angry that I have written in englishe, let them remember that the grekes wrote in greke, the Romains in latin. . . .

Pure scientific literature continued to be written almost exclusively in Latin. Vesalius had written his book in Latin, and Harvey was to write his in the same language. Nevertheless, the "Haven of Health" exemplifies the spirit of the times. A positive statement is seldom made without marginal reference to the authority for such statement. It is a rare page that has not at least one marginal note, while many have three and sometimes four such references, so that they resemble the pages of a cross-reference Bible. Aristotle, Hippocrates and Galen are frequently referred to. For the author makes no claim for originality:

> And if they [the readers] find whole sentences taken out of Master Eliot his Castle of Health,[1] Scho. Sal.[2] or any other author whatsoever, that they will not condemne me of vaine glorie . . . for I confess that I have taken Verbatim out of others where it served for my purpose, and especially out of Scho. Salerni; but I have so interlaced it with mine owne, that (as I think) it may be better perceived. And therefore seeing all my travail tendeth to common commoditie, I trust everie man will interpret all to the best.

[1] Sir Thomas Elyot, "The Castell of Helth," London, 1534.

[2] "Regimen Sanitatis or Schola Salerni," a work on health in Latin hexameters composed by Robert, Duke of Normandy and son of William the Conqueror. The annotations to this work by various subsequent writers were of more value than the original composition. It is said to have gone through no less than 160 editions.

It is of course necessary for Cogan to explain in these prefatory remarks the form or order which he observes in assembling his material:

> Such as have written of the preservation of health before me, for the most part have followed the division of Galen into things not natural, which be fixed in number, Ayre, Meate and Drinke, Sleepe and watch, Labour and rest, emptiness and repletion, and Affections of the mind. However, Hippocrates in the sixth book of Epidemies, set down Labour, meate, Drinke, Sleepe, Venus, all in a measure, as a short summe or forme of a man's whole life touching diet.

In the disagreement of such high authorities, our author is able to exercise some choice in the "order" of his book. Such manipulations of authority are not infrequent. For instance, the "Haven of Health" is written primarily as a guide for students. This circumstance provides the author a means of brushing off some of the dusty accumulations of the ages, because Aristotle, Hippocrates, Galen and the rest did not limit their field in this way. Those things which are good for laborers may not be good for students, for we are constantly reminded that "Great labour overcometh all things," especially in the way of dietary indiscretion. Thus, "In some shires in England they use in Lent to eate raw Leekes and hony, with Beanes or Pease sodden, but what Rustickes do or may do without hinderance of their health, it is nothing to students: for Gross meate is meete for grosse men." And, furthermore, "pease potage" can not be recommended for students, but "I leave it to Rustickes who have stomacks like Ostridges, that can digest hard iron. And for the student I allow no bread but that which is made of wheat."

Although Cogan does not always hold to current views and sometimes goes out of his way to disprove them, this is never done by ready recourse to his two good eyes, but, consonant with the spirit of the times, by quotations from authority. Thus in order to prove that rabbits are not hemaphroditic he does not recommend examination of the animals themselves, but says: "The opinion which some holde, that everie hare should be of both kindes, that is male and female, is disproved by Matthiolus . . . as untrue."

The book proper opens with a discussion of the geography and physiography of the British Isles, especially as they are in contrast to the Roman world. This is evidently a bit of hocus pocus so that when our author disagrees with the older philosophers he may be able to show that the differences are more apparent than real and are bound up in differences in climate, topography, or what not. Thus, although the Salernian school discountenances the use of beef, and Galen too, disapproves its use, saying "It maketh grosse blood and engendereth melancholie," Cogan is able to approve its use as follows: "All these authors (in mine opinion) have erred in that, they make the Biefe of all countries alike, For had they eaten of the Biefe of England, or if they had dwelt in this our climate, which through coldness doth fortifie digestion, and therefore requireth stronger nourishment."[3]

After this safety valve introduction we are justified in going on with the subject in accordance with the aforesaid schedule. First,

> When you are arisen from sleepe, to walk a little up and downe, that so the superfluity of the stomacke, guttes and liver, may the more easily descend, and the more easily be expelled. . . . Morover to extend and stretch out your handes, and feete and other limmes that the vitall spirites may come to the utter partes of the body. Also to combe your head that the pores may be opened to avoide such vapours as yet by sleepe are not consumed. Then, to rub and cleanse the teeth. For the filthiness of the teeth is noysome to the braine, to the breath, and to the stomacke.

When the "vitalle Spirites" have wandered to their proper stations, and the vapours have arisen from the head, exercise is in order, provided the oracle is favorable. The oracle consulted in this case is the color of the urine which should be neither too pale nor too red. As an example of the benefits to be procured by exercise, the case of Milo Crotoniates is brought forth. Milo was a gentleman of no mean ingenuity and initiative. For he it was, who, in the lack of Whitney exercisers, made use of available material, and by carrying a "calfe every day certain furlongs was able to cary the same being a Bull." Perhaps all the young married men of the neighborhood engaged in the pastime. Perhaps classes were formed. Perhaps in those days astute men of affairs neglected their business to carry appealing young calves, or the same being bulls, along the country lanes just as in 1919 otherwise sane men are known to spend hours at a time whacking little white balls across green fields. Who shall say that the golf widow of 1919 is not the lineal descendant of the "calfe widow" of 1594?

Further exercise suitable for the development of the various parts of the body are set forth. Tennis is stated to have been

[3] I have omitted no part of this last sentence. It is complete as quoted. It is quite usual to leave a loose end hanging over in this way, ready to drop off and endanger traffic.

recommended by Galen as an exercise proper for all parts so that "Those founders of Colleges are highly to be praised, that have erected Tenis courtes." Cogan, of course, had never heard of the dilation of the blood vessels in the walls of the intestine during digestion, but nevertheless discountenances hard exercise after meat, because, we are told, "Hastie moving driveth the natural heate from the inward parts."

That so many of the recommendations made in an empirical spirit have been supported by later scientific findings makes the book especially interesting. One is frequently surprised at the wise counsel given, only to be later amused at the seemingly absurd reason which supports the advice. However, it is yet too easy to find a physician who will explain the use of certain remedies for rheumatism as due to their ability to dissolve uric acid, the reliance on quack remedies is still too widespread, for the modern reader to assume any air of superiority over the sixteenth century writer. In reading his book, sensations are aroused akin to those provoked by correcting a set of examination papers. High hopes of deep knowledge are raised, only to be rudely dashed to the ground by the shallowness revealed in excessive loquacity.

But some of Cogan's explanations might very readily be accepted by a large group of non-scientific men to-day. In this respect I believe the average man of science has an exalted idea of ordinary "lay" opinion. Within the last month the writer heard an intelligent man, who had seven years ago graduated from one of our foremost American colleges give the reasons why lemon and milk had better not be eaten together. "The essence of lemon is citric acid, the essence of milk is malt, and of course the two do not mix." In the subsequent development of these novel views it appeared that the modern cow produced Horlick's Malted Milk, or milk that needed only to be evaporated carefully in order to yield the proprietary preparation. But to proceed—

Many of the home remedies now in use or their prototypes were known to Mrs. Crotoniates. Who, in his childhood days has not had onion concoctions inflicted on him by a well-meaning, but erring grandmother? Cogan had.

> And if any be troubled with the cough, and be overlayed with abundance of fleume in the breast, so that they can not easily draw their winde, let them rost Onions under hotte embers and eate them with Hony and Pepper and Butter morning and evening, and within few dayes they shall feele their breastes loosed, and the fleume easily to be avoided.

The lowly prune is shown to have a long and a proud lineage.

> Prunes being eaten first, beside that they are pleasaunt, they loose the belly. . . . I have written the more of Prunes, because it is so common a dish at Oxford.

The unchangeableness of college boarding houses is evidently not a new thing under the sun.

In the section on labor considerable advice is given regarding study, the assumption being that this is an activity with which a student may be not unacquainted. Morning is the best time for this, as then the "planets are favourable, Sol, Venus and Mercurie being near." One should work earnestly for an hour,

> then the hair comber upwards forty times and the teeth rubbed. No new reading to be done in the afternoon, as now the sun is not convenient. But nothing is more hurtful than study at night.

Let the freshman gloat. But his gloating will be short-lived, for, our author continues,

> Good students will spare no time from their books. . . . And if they wax pale with over much study, it is no reproche, but a verie commendable signe of a good student.

As for mental recreation, the playing of gambling games is discouraged (somehow the reader obtains the idea that this advice is rather half-hearted) but chess is recommended as an easily accessible pastime which students may have available at all hours. A prime source of recreation "for a mind wearied with study and for one that is melancholie (as the most part of learned men are) is music." Aristotle is properly given credit for this bit of wisdom.

Under the caption "Meate" a great variety of edible substances, together with some of the medicinal plants are discussed and classified according to their "hotnesse or coldnesse, dryness or moistness."

> Goates flesh . . . is dispraised of Galen. Because, beside that it breedeth ill bloud it is tarte. Yet kidde is commended of him next unto pork. But Auicen and the sect of the Arabians, doe prefere kids flesh before all other flesh, because it is more temperate and breedeth pure bloud; as being in a meane betweene hote and colde, subtill and grosse. So that it can cause none inflamation nor repletion. . . . But it is not convenient for labourers because great labours would soone resolve the juice engendered thereof.

"Rammes mutton" our author leaves "unto those that would be rammish, and old mutton to butchers that want teeth

. . . Pork is most like human meat" and the "inward parts" of swine resemble the inward parts of man. For these reasons "some" have eaten human meat instead of pork. This atrocity our author attributes to "certain Scots." That the English land question was fomenting even in the sixteenth century appears from a long discussion on the evils of giving over large tracts to the raising of deer,—tracts which, if used for cattle, would be able to produce more food for the poor man.

Cogan evidently realized that various parts of animals do not necessarily nourish homologous parts of the human body, for he says: "That heads do not necessarily nourish heads best is seen by people with the falling sickness (a disease of the head), wherefore, I think that reason proceeded first out of a calves head or a sheepes head."

In these war times, the modern reader will sympathize with the author's observations on the eating of fish. We learn that in the sixteenth century England had a Hoover in no less a personage than good Queen Bess herself. The queen had ordained Wednesday for the eating of fish as well as Friday and Saturday, "not for holiness purpose, but as a civil policy. For the many lakes provide much good fish," and if the ordinance were obeyed, one half the days of the year (when fast days are included) would be meatless days. But some are selfish (sighs Cogan) and do not obey.

In this section we are told that "Milk is blood twice concocted. . . . A windie food, but can be made less windie if boyled." It is corrective of melancholy—a property which Metchnikoff would have undoubtedly ascribed to the reduction of intestinal putrefaction following its ingestion. Variety of foods is best (as the obvious way to supply a mixture of amino acids and a sufficiency of vitamines?), according to Hippocrates, for "Everie offence in dyet is wont to be more grievous on a slender diet, than a full dyet, and for the same cause, a very spare, precise and exquisite dyet is not so sure for them which be in ill health, because the breaking thereof is the more grievous." This advice has received ample justification in Germany within the past two years, where scientific studies have shown that medical students existing on the official civilian diet were completely unable to maintain health after taking a moderately long walk. Alive to-day, Cogan would doubtless be of the high-protein school.

The higher level of metabolism of childhood seems to be appreciated since it is advised that "Children, especially lively ones, should not fast, but should eat more." The idea of the calorie and the fine conception of energy relations as applied to food requirements seems almost realized in practise, while the theoretical explanations set forth to support the advice seem as usual, absurd in the light of our fuller knowledge. Thus, to explain the wise advice that less be eaten in summer, the reader is informed that at this season of the year the perspiration is more copious, giving rise to loss of digestive juices. Carlson is not the first to advance the idea that the feeling of hunger is associated with certain contractions: for, to quote again,

> When to eat is best told by hunger, hunger riseth by contractions of the veynes, proceeding from the mouth of the stomach, for want of meate, for as Leonard Fuchsus teacheth "True hunger ariseth of the feeling of want, when the veines do draw from the stomack as if they did milke it or sucke it."

Perhaps the widest departure from modern conceptions is found in the discussion of "Drinke." But even here the final impression is the same as might very well be obtained from reading a number of up-to-date tracts on the subject; that is, that the whole subject is a matter of controversy. Prohibitionists would surely not agree with Cogan, while, on the other hand, his ideas would be far more to their taste than those of earlier writers quoted.

Water may safely be consumed in England at certain times, provided due precautions are taken. Sanitary engineers will be glad to learn that the relative purity of waters may easily be determined by dipping linen cloths into the samples submitted, the notion being that the cloth drying soonest has been dipped in the purest water. "Some" in certain parts of the country are known to use no other beverage than water. "For young folkes and those of hote complexion, it doeth great harme, and sometimes it profiteth." This is evident pussy-footing. But it is not to be used by the "olde, phlegmatic or melancholie." Wine is the gift of God to man. Does then (Cogan plaintively asks) God love the Germans and French better than he loves the English, since he has given these people a climate so much better suited to the raising of the grape? No, Britons need not fear. This uneven distribution of favorable climate fulfills God's good purpose. He has made England dependent on the Continent for its wine supply so that a spirit of cooperation and of brotherly love will be engendered among the people of these nations.

"Wine is disliked by one in a thousand and these be those of a doggish nature, while it is good for clergymen of ready wit." Students, however, are to be cautioned, as they "have but feeble brains," so that excess of wine is probably the cause why so few students have profound knowledge and ripeness. Plato forbade the use of wine up to the age of twenty-one, while Galen thought wine should not be indulged in until the age of thirty-five. (Cogan is well above this age.) On the other hand, Arnoldus says "Hipp" thought drunkenness was sometimes expedient in that it provoked vomiting and was for this reason cleansing. "Hippocrates counseled drunkenness once a month forso we might be procured to vomit." Once more Cogan ventures to express an opinion of his own. He believes that one had better be induced to vomit in other ways, less pleasant perhaps, but also "less beastly."

As regards "sleepe," the toxin theory—which in 1919 has yet to be definitely rejected—is supported:

> Here is showed by what meanes sleepe is caused. That is, by vapours and fumes rising from the stomacke to the head, where, through coldnesse of the braine, they being congealed, do stoppe the conduits and wayes of the senses, and so procure sleepe, which things may plainly be perceived hereby: for that immediately after meate we are most prone to sleepe.

We are all doubtless familiar with the common idea that lettuce causes drowsiness. This idea originated before Cogan's time, probably with the ancients, for he says:

> I procured sleepe of set purpose: for it was grievous unto me to wake against my will. . . . Therefore Lettuce eaten in the evening was my only remedie.

It is only a few years since Mrs. Winslow's Soothing Syrup reformed. Under another name, a similar substance, unregenerate, was used by the Italian women before Cogan's time.

> And the women of Salerne give their children the powder of the white Popie seedes with milke, to cause them to sleepe, it may be given otherwise for the same purpose, as in Posset, drinke, or in aleberie, or best of all in a Cawdle [cordial] made of Amondes and hempseede.
>
> Nowe that I have spoken sufficiently of Labour, Meate, Drinke and Sleepe, it remaineth only that I speak of Venus. . . . And as it is last in order of the wordes, so ought it to be the last in use.

These chapters on Venus are interesting. The author's advice regarding the exercise of the sexual functions is not so advanced as that given by the most enlightened medical men, perhaps, but his views are certainly nearer the truth than those of a large part of any modern population. Be it remembered that we still have with us a few well-meaning though poorly informed physicians of the old school who do not hesitate to advise incontinence for what they would call "meaty" young men. Among three classes of men named by Cogan as able to practise continency, clergymen are said to have this power conferred by the grace of God.

> Yet I do not think the gift of continence so general as it was supposed in times pwast, when all the Clergie were restrained from marriage.

Some stories are then told which indicate that either the gift of God was not always comprehensive enough, or human weakness was sometimes so powerful that all contingencies were not provided for.

Cogan advises thirty-eight as the correct time for men to marry, and eighteen for women. At this time a man has attained self-control, so that the size of his family need not exceed his plans, while the woman is easily ruled. "The first dish that is served up at the marriage feast is miserie and the second is care," proclaims our author. But this is only hearsay. Cogan himself did not marry until three years after the first edition of "The Haven" was published.

"Appended" to the main part of the book is a discussion of the plague, which has been "Twice in Oxford in my time within 12 yeares, being brought from London both times: Once by clothes, and another time by lodging of a stranger." In reality these chapters are as much a part of the book as any of the others. I suspect they are "appended" merely because Cogan can not find any authority for introducing such chapters into a work on hygiene. The cause of the disease is "The influence of sundrie starres, great standing waters never refreshed, carraines lying long above ground, much people in small roome, living uncleanly and sluttishly, that is, and one principall or generall cause, that is, the wrath of God for sinne."

Ways of avoiding the plague are given, one of which is to inhale the fumes produced by pouring acetic acid over heated copper. But the most effective measure is precipitant flight. The fatalistic attitude toward the disease is seen in the last chapter of the book:

> Yet thankes be to God hitherto no great plague hath ensued upon it [the plague of 1577]. But if it do (as I doubt it will) unless we speedily repent either the pestilence, or famine, or warre, or all three, I say if it do, then must we do as the Prophet David did, offer a sacrifice unto the Lord, a contrite and humble hart: and say with that holy Prophet Let us fall now into the hands of the Lord, for his mercies are great, and let us not fall into the hand of man. And I beseach God that whensoever it shall please him to visite our offences with his rod, and our sinnes with scourges,

that we may likewise escape the hand of man and fall into the hand of the Lord, to whom be all glorie, prayse, and honour for ever and ever. Amen.

Who was this Thomas Cogan, whose memory has survived three centuries? Born in 1545, he received his B.A. from Oxford in 1563. An M.A. followed in 1566, and a degree of bachelor of medicine in 1574. A year before he received his medical degree, Cogan wrote the "Well of Wisdome . . . containing Chiefe and chosen sayings which may leade all men to perfect and true wisdome as well to Godward as to the worlde . . . gathered out of the five bookes of the olde Testament. . . ." This book was not published for several years.

After obtaining his medical degree, Cogan settled in Manchester, where he was, we are told, not only the leading physician, but high master of Manchester Grammar School, and a "classical scholar." One does not give white elephants to one's alma mater, so we know with what esteem our author regarded Galen and his work. For in a gift to Oriel College in October, 1595, he included five volumes of Galen's "Works," besides Thomas Geminies' "Anatomy" and Malthiolus' "Commentaries on Dioscorides."

At fifty-eight he resigned the position in the grammar school for the purpose, I suppose, of devoting more time to his medical practise. This must have been reasonably large, for he seems to have been very well connected and very well known in the neighborhood. In his spare moments he now prepared a selection of Cicero's letters for school-boys, which was published under the title "Epistolarum familiarum M. T. Circeronis. . . ."

Unless a man's gift to the world be far greater than its Cogans are destined to give, the interest after three hundred years is, I suppose, not so much in his attainments as in the character of the man himself. The reader of biography in 2200 will perhaps remember but few of even Huxley's monographs. The vast amount of work which was the center of his interest will be forgotten. That, however, Huxley successfully engaged in a public altercation with Bishop Wilberforce will long live in the memory of man.

Thomas Cogan died in 1607. Of his will, one sentence reveals the man. Given the single bone, the character of the man may be reconstructed. For, after bequeathing "certain moneys to the poor in Manchester" and to his "poore neighboures . . . all my Shirts, one appece," he says, "I give to every Scholler of the ffree Schoole in Manchester, 4 d. apeece. . . ."

John Bunyan or Milton would have moralized over the gift. Dickens would have become intensely sentimental. Tears would have freely flown. Samuel Johnson would have excluded Scotch scholars from the benefits to be conferred and would have stipulated that the money be spent on something which no boy of tender years should possess. But not Thomas Cogan. He knew boys. And schoolmasters seldom do. In knowing boys, he knew and understood men. And after all, it is because of this knowledge and because of the injection of his personality into the book he wrote that makes it still interesting.

THE DISADVANTAGES OF BEING HUMAN

By Professor B. W. KUNKEL

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MAN early came so habitually to regard himself as the crown of animate nature, "the masterwork, the end of all yet done" in Milton's words, that he long ago arrogated to himself the perfection of the gods and to-day ordinarily blinds himself to the natural imperfections of his body and the disadvantages of being human until his machinery is in such poor working condition that he has to go to the doctor's. Far back in the days of pre-history, some genius suggested that man was made in the image of god and from that time on, there has been a pride of birth on the part of man, reaching a climax with the Junkers of Prussia and their super-manhood.

From time to time, however, prophets and seers have abundantly appreciated the imperfections of humanity, as when the Psalmist exclaims in an outburst of pessimism: "I am a worm." The ministers of the Scotch church in the seventeenth century, says Metchnikoff, quoting Buckle, the historian of civilization, thought there was nothing more surprising than that the earth could contain itself in the presence of that horrid spectacle, man, and that it did not gape as in former times, to swallow him in the midst of his wickedness. Even in our own time, Mark Twain more than once bemoaned the fact that he was a man and that humanity had very little to be proud of. The consideration of the physical disadvantages of being human is no new theme, but in the flush of victory over the arrogant Huns under the leadership of would-be super-men, it may be especially salutary to attend to this subject for a short time in order that the pride of creation may the better appreciate how far short of the gods he falls. In spite of thankfulness for being fearfully and wonderfully made, there are, as I shall show, some respects in which we may indeed be in fear of our precarious machinery and stand in amazement at the maladjustments of our own bodies.

At the same time that I wish to point out especially the disadvantages of being human from the bodily standpoint, I would not leave the impression that man is nothing but a bundle of mistakes and a poorly built machine. In spite of obvious defects he is, like every living creature, closely adapted to his environment and must, within limits, constantly adjust himself to changes in the environment. The crawling *Amœba* no less than the Marathon runner and the calculating philosopher are from moment to moment adjusting their internal relations to external relations with wonderful nicety. The muscles of the Marathon runner are absorbing oxygen as well as fuels necessary for their explosive action in contracting. The brain of Newton in contemplation of the law of inverse squares is absorbing molecules from the blood and discharging different molecules which have been produced by the activity of the brain cells. The failure of the heat-regulating mechanism to keep the bodily temperature within a few degrees of 98.6° Fahrenheit, or to respond to the increased temperature of the bake shop or boiler room causes illness and possibly death. From certain points of view the human mechanism is marvellously adapted and warrants man's high regard for himself. But in no case is adaptation to environment absolutely perfect. The more closely an organism is investigated, the more apparent is it that there are present disharmonies and imperfections. Johannes Müller sixty-odd years ago showed that in spite of the perfection of the eye as an optical instrument, it is very imperfect in correcting aberration of light. An ordinary camera or microscope made with so little regard for optical axes and irregularities of curvature of lenses would be a most unsatisfactory instrument. Helmholtz, to whom we are indebted for so large a part of our knowledge of the optics of the eye, says: "Nature seems to have packed this organ with mistakes, as if for the avowed purpose of destroying any foundation for the theory that organs are adapted to their environment." And yet the eye does very well for most of us and we are thoroughly happy in the possession of this structure whose lenses are not exactly curved and centered!

Disharmonies abound in practically all forms of living things. Rudimentary structures, which have outlived their usefulness, occur in all higher animals and are constantly "getting in wrong" with things about them. But besides the rudimentary structures there are others which may be regarded as incipient structures which have not yet attained the size and complexity necessary for their perfect functioning. Besides imperfect structures, a great many animals exhibit instincts or reactions to stimuli which seem to go counter to the best interests of the individual and the race. Perverted tastes in man are no less destructive than some perverted reactions in animals. For instance, the moth flying into the candle flame represents a maladjustment of the moth's mechanism and its environment which results in the destruction of untold myriads of moths. The nervous mechanism of the moth in this case is as much out of correspondence with its environment as the broken shaft of an ocean liner which in its rotation beats a hole in the side of the hull.

It is hard to explain in most cases the origin of these disharmonies, although in general it may be said that they represent a failure on the part of all the organs of the body to keep pace with the changing environment, or of the several organs to keep pace with each other. Some organs seem to be less plastic than others; some, on the other hand, apparently get into the habit, so to speak, of changing too rapidly. To enter into a discussion of the causes of these maladjustments that are disadvantageous to the organism would take us too far afield into the fundamental problem of biology, the origin of variations. It is enough at present to remember that the survival of the fittest is in spite of these defects.

Many of the defects of the human body may be referred back from the mechanical point of view to the present habit of striding about on two legs, a habit of very recent phylogenetic development—a fact vouchsafed by the length of time the infant crawls on "all fours" and the slowness with which it assumes the bipedal method of locomotion and exhibits a fairly well adapted structure for the upright position. So late in phylogeny has this position been acquired that many parts of the body have not yet become perfectly fitted for this remarkable experiment. So closely adjusted to each other, however, are the different parts of the body that any change in one part almost always brings about a change in every other part. As we shall have occasion to show, the upright posture has affected directly the skeleton, the muscles, the blood vessels, the jaws and teeth, and probably indirectly other parts of the alimentary canal and the organs of respiration; while many students of human evolution regard the abnormal development of the intellect of man as a direct outcome of the upright position with the freeing of the hands to learn of the environment by handling and the elevation of the principal sense organs in order to give man a broader horizon.

Let us turn first to a consideration of some of the defects of the skeleton which are associated with the upright position. The ancestral foot of man was characterized by the slant of the sole in relation to the axis of the leg so that the sole could be applied more perfectly to the cylindrical trunk of the tree, to which primordial man was fairly well adapted. In order to bring about this position of the foot, the heel bone is skewed and set off slightly to one side in such a way that when the anthropoid ape of to-day attempts to walk on the ground, it is necessary for the sole of the foot to be turned toward the middle plane of the body with the heel bone brought beneath the axis of the leg and the weight of the body borne on the outer edge of the foot. Man's heel has moved over somewhat further toward the inner side of the foot in order to bring the sole squarely on the ground, but the parts have not become perfectly adapted to the new arrangement for there is still a little weakness that manifests itself as fallen arch in thousands of human beings. The weakness of the arch in great measure is due to the long stretch between the ball of the foot and the heel and an imperfect support of the arch on the inner margin of the foot, a defect which is remedied often by the surgeon in treating fallen arches by extending the heel of the shoe forward along the inner side of the instep and also by building up the inner side of the heel to throw the sole of the foot inward and shift the weight of the body more to the outer side of the foot.

Another defect of the skeleton occasioned by the upright position is in the pelvis, which is attached to the vertebral column and encircles the posterior end of the alimentary canal and genital ducts and affords attachment of the hind legs. In the quadrupeds this part of the skeleton serves almost entirely for the attachment of the hind legs and plays only a very secondary rôle in supporting the viscera which are suspended along the entire length of the body cavity by mesenteries. As soon as the trunk assumes an upright position, however, the weight of the viscera pulls toward the tail instead of toward the underside of the animal and the mesenteries afford a far less efficient support. To compensate for this, however, the pelvis changes its function somewhat, and consequently its form, and instead of serving simply as an attachment for the limbs to the vertebral column, it now becomes a basin to aid the mesenteries in supporting the viscera by a partial closing together posteriorly so that a comparatively small opening is allowed for the passage of the alimentary canal and the genital ducts, and a flaring outward at the anterior end. This is not inconvenient or harmful in the least in the male, but in the female it increases the difficulty of parturition seriously, especially among the white races which have somewhat larger heads and less compressible skulls at the time of birth. Complete support of viscera and sufficient passage for the fetus at birth are mutually opposed to each other with a consequent disharmony.

The upright position has brought about several disadvantageous maladjustments in the blood vessels. Unlike the quadrupeds, in which the axis of the body is carried habitually more nearly parallel with the ground, in man the axis is vertical so that the blood vessels especially of the lower part of the leg must support an unusually tall column of blood and thus be subjected to a relatively great pressure. This pressure is borne by the arteries as well as by the veins, but the strong muscular walls of the arteries are easily able to withstand the strain of the weight of blood lying above them and the thinner walls of the deep-seated veins supported by the surrounding muscles are not likely to give way. But in addition to the deep-seated veins there are several superficial veins which lie beneath the skin only and so are deprived of the added support of the surrounding muscles. The walls of these vessels frequently give way, particularly in those who stand for long periods and whose blood vessels may be slightly weak. When these vessels rupture under the pressure of the blood, varicose veins result which have discommoded thousands upon thousands of human beings. The offending blood vessels may be supported by bandages, or in extreme cases they are generally removed by the surgeon and the blood which ordinarily passed through them finds its way through other vessels which gradually enlarge to accommodate the increased blood flow thrown upon them with no apparent inconvenience.

The veins of man exhibit further lack of adaptation to the upright position by the arrangement of the valves. These valves, which are pockets to prevent the blood from flowing away from the heart, are obviously important only in those veins which have a vertical course and in which the blood flows upward to reach the heart. Thus, the valves are found for the most part in the veins of the fore and hind limbs and in the intercostal veins. Were the valves thoroughly adapted to the upright position they would be quite differently distributed. There would be none in the veins between the ribs which have a nearly horizontal position in man and there would be an abundance of them in the large vessels entering the heart from the abdominal region. The great vein which receives blood from the legs and kidneys and the great vein which brings blood from the stomach and intestines are both without valves so that the circulation in the lower extremities and the abdominal organs is retarded and the pressure on the veins of the legs is sometimes seriously increased. Furthermore, congestion of the abdominal organs, especially the liver in which the circulation of the blood is at best sluggish, is frequent in the human race, a condition which would be improved if there were valves in the veins leading from the different organs which would relieve the tendency to back pressure and consequent retardation of the circulation.

The absence of valves in the great abdominal veins works hardship in another way. In case the extensive vessels of the alimentary canal suddenly enlarge as they do under the stimulus of a blow on the solar plexus, the blood is drained rapidly from the brain and the recipient of the body blow falls in a faint. With valves in the veins of the trunk to prevent the back flow of blood, the vessels of the brain would not be drained so rapidly and the insensibility would not follow such temporary derangements of the abdominal circulation.

The straightening up of the body involves the extension of the trunk on the thigh which exposes certain vessels dangerously. This condition is met with in no other vertebrate, and consequently is one of the most highly specialized conditions in the human body. Whereas in a dog or other quadruped, the groin is deeply seated between the thigh and the abdominal wall, in man it is fully exposed and unprotected. Just below the groin on the front of the thigh, a little toward the median side, is the superficial femoral artery, which is one of the principal channels by which blood is carried to the leg. In an animal with the thigh habitually bent on the trunk, this superficial vessel lies deep in the crease between thigh and trunk, securely protected from tooth and talon of the aggressor. But not so in man. With the feet spread in order to give him a broader base and a more secure balance, the femoral artery lies exposed in a most dangerous way, ready to be torn open by talon or spear. The genital organs are also dangerously exposed in upright man while in the quadrupeds they are fairly secure against frontal attack.

Not the least of the disadvantages of the upright position is the exposure of the entire abdominal wall to injury. As if it were not enough to expose to teeth and talons a large area which is unprotected by skeleton, the whole trunk is flattened and broadened so that a larger target for the attacker is afforded and some vulnerable points are dangerously exposed. It is hardly necessary to call attention to the solar plexus which is but poorly protected behind only a moderate rampart of viscera and which must in the history of the human race have caused the downfall of many a fighter before the modern pugilist came to realize the importance of this weak point of human anatomy. In this connection, too, it is interesting to note that some of the most skilful pugilists assume a crouching position in the prize ring which incidentally protects the defenseless abdomen more perfectly and presents a more formidable rampart to the enemy.

Turning aside from some of the defects which are the immediate outcome of the upright position we may turn for a moment to some defects which are not so closely connected with standing "upright, with the front serene."

The skin of man has lost certain structures which render it a less perfect hull for the internal organs than is the skin of many of the lower mammals. The coat of hair, so scanty over most of the surface, no longer affords a protection against cold or teeth and talons like the shaggy mane of the lion or the heavy pelt of the bears. In fact, the imperfect hair follicles of man are a positive disadvantage, for bacteria lodge in these tiny cups and often set up inflammation, giving rise to various eruptions of the skin. In the history of the race, thousands of men must have suffered untold annoyance from this cause and in many cases serious blood poisoning must have followed through the injury of these eruptions. The scanty coat of hair may have proven an advantage by affording poorer lodgings for fleas and other bodily vermin, but this advantage could hardly compensate for the exposure to cold and mechanical injury which a loss of hair involves.

Together with the loss of hair has also gone an extensive loss of dermal musculature by means of which the skin can be twitched, as is well seen in the horse when troubled with flies. This extensive layer of muscle has disappeared from the human species except on the front of the neck and the face and the scalp. Unlike the quadrupeds that can scare off insects without moving the limbs, man is under the painful necessity when disturbed by crawling insects of using a limb to chase off the offender like the proverbial Jerseyite in the mosquito season. It is conceivable that many of our forbears must have lost their balance in the tree tops in trying to drive off an insect with hand or foot. The advantage that would arise from being able to wriggle the skin independently of the limbs and thus overcome the irritation of tickling insects is obvious.

The skin muscles in man, as already said, are limited to the front of the neck and the head. By means of them mankind is as well as some of the apes, able to express various emotions. We draw down the corners of the mouth to express sadness and wrinkle the forehead in perplexity, and draw the corners of the mouth upward to indicate hilarity of spirit; but these functions are decidedly secondary in importance to the scaring off of insects.

There are rudimentary muscles attached to the external ear which are entirely comparable to those by which the ear of the grazing animals particularly is directed toward the source of the sound and by virtue of which the acuteness of the hearing is increased considerably, a fact borne out by the practise of those whose hearing is defective of holding the hand to the ear and making a kind of funnel with the large end toward the source of the sound. The loss of mobility of the ears has probably not been compensated.

The defects of the eyes as optical instruments have already been alluded to. But the defects here are as nothing in comparison with those of the neighboring organ of smell. So imperfect is the sense of smell in man that it is only by courtesy that we may be said to have such a sense. We recognize pleasant and disagreeable odors, if they are sufficiently concentrated, together with flavors, which we refer quite generally to the sense of taste; but the delicate odors that are appreciated by many of the lower animals are totally beyond our powers. To the dog with its sense of smell a whole world of sense impressions of which we know absolutely nothing is open. The human subject is generally unable to appreciate the difference in odor of the secretions of the skin under different strong emotions although there is abundant evidence that the nature of these secretions is modified by emotions. On one occasion I was greatly terrified at the sight of my small child calmly sitting on the edge of a roof upon which she had climbed, and, although I had just returned from my bath, I was conscious of a most fetid odor from my skin immediately after I had rescued the child—the odor of fear. With a sense of smell acute enough to perceive the passing variations in our bodily secretions would our knowledge of mankind who come in contact with us not be vastly increased? Sherlock Holmes equipped with a sense of smell keen enough to differentiate between the odor of sanctity and deceit would have made the feats of Conan Doyle's hero pale into insignificance! Primitive man might have escaped many an enemy by perceiving the odor of the skulking stranger suffering from the necessity of concealing his identity, and fearing discovery.

Nor is it alone in the function of the organ of smell that man is defective. The structure of that organ is rudimentary as might be expected and like all such structures is liable to great variation in form and to various diseased conditions. The sensitive organ of smell is spread out over a most complexly folded scroll of bone in the nose so that there is little chance for any fraction of the air drawn over it to fail to come in contact with the sensitive membrane. But these turbinal bones in the human subject are greatly reduced in size in comparison with our more sharp scented animal cousins and are often so deformed as to make little pockets in which the secretions of the nose accumulate and undergo decomposition. The disinfecting of the nose and the removing of these troublesome pockets in which mucus accumulates is an important work of the nose specialist. And this is largely due to the rudimentary condition of this sense organ whose function we of polite society are all too prone to taboo.

Before leaving the organs which cooperate in the function of respiration, it is of interest to note a trivial defect in the lungs which may have been the cause of countless deaths in the past and which seems to indicate a failure on the part of the body to be perfectly fitted for its environment. As is well known, the trachea passes from the mouth, or more properly the pharynx, to the lungs, dividing into the two bronchial tubes. The right bronchus is given off from the trachea at more nearly a right angle than is the left so that mucus rolling downwards, or disease germs carried down by the air current, find their way into the left lung with greater frequency than into the right lung. Correlated with this difference in the form of the two bronchi is the occurrence of pneumonia infections. In the typical case of lobular pneumonia, the congested areas cluster around the extremity of the left bronchus more closely than the right in exactly the fashion that would be expected when it is remembered that the germs of pneumonia do not have the power of independent locomotion but are wafted whither the wind listeth and multiply wherever they find a favorable environment.

The respiratory organs have suffered directly as a result of the upright position of man, for the emancipation of the forelimb from supporting the weight of the front part of the body has brought about a great change in the movements of respiration which have not been accompanied by perfectly adapted changes in the lungs. The anthropoid apes in captivity and man are very prone to tuberculosis of the lungs which gains a foothold generally in the more poorly ventilated parts of the lungs, the apices. In the respiratory movements of the anthropoid apes and man the diaphragm plays a very important part in enlarging the capacity of the thoracic cavity. By its contraction, the convex, domelike diaphragm is flattened and the length of the chest is thereby increased. But in addition to the diaphragm are the intercostal muscles and certain auxiliary muscles of respiration which extend from the shoulder blade to the ribs and from the arm to the ribs, the serratus and pectoral muscles principally. With the arms free, these last named muscles, which are very strong, in contracting draw the shoulder blade ventrally to increase the reach, as for example in striking a blow with the fist. With the arms free, the ribs serve as the fixed point of attachment and the shoulder blade is the movable portion of the mechanism. In the quadrupeds the relative importance of the movements of the diaphragm and the external muscles of respiration is almost reversed. In the quadrupeds bearing a part of their weight on the forelimbs, the arm becomes fixed and a contraction of the serratus muscle results in a raising of the ribs and consequent enlarging of the cross section of the chest. The gymnast swinging from horizontal bar or trapeze fixates his arms so that these muscles in contracting pull up the ribs and ventilate the apices of the lungs particularly well. On the same principle, in some diseased conditions in which shortness of breath is experienced, the patient finds it necessary to rest his hands on the back of a chair or other support in order to get his breath. But in so doing he is virtually becoming quadrupedal, at least to the extent that his arms become fixed and the strong external muscles of respiration aid in the elevation of the ribs in a way which is impossible where the arms swing freely.

The liberation of the forelimb from the work of supporting the body weight has been responsible further for several changes in the front part of the digestive system which are not unmixed joys although our ideas of human beauty are curiously enough closely bound up with them. The hands have become prehensile organs and the earlier prehensile function of the jaws has been lost and the jaws have shortened. By becoming a hand feeder, man's teeth have grown smaller and more closely crowded together. The teeth no longer have the important function which they once had, for the incisors are aided by the bare hands or knives and the grinders are rendered less important by pestle and grinding mill. The wisdom teeth show several unmistakable signs of degenerating. They are smaller than the molar teeth immediately in front of them, they are frequently imperfectly cut, and the cusps and cavities of the grinding surfaces fit with their opponents less perfectly than in the teeth in front. In fact the wisdom teeth fail to be cut in about ten per cent. of adult human beings. With the imperfect functioning of the wisdom teeth is a great tendency to decay, and on account of the delicacy of the membrane about their roots which is not stimulated as that around more frequently used teeth, infections and abcesses are much more common.

Even the milk teeth of children are weakened and become liable to decay in a way which indicates that they are far from well adapted to their purpose. How far the feeding of gruels and other foods offering little resistance to the teeth in chewing plays a part in inducing or facilitating decay, it is hard to say, but examination of the skulls of children of primitive peoples as late as the beginning of the Christian era shows that it is only very recently that the milk teeth have fallen so far short of expectations.

Even more rapidly than the disappearance of the teeth has been the shortening of the jaws which has brought about a condition giving much work to modern dentists. The shortening of the jaws has crowded the teeth together so firmly that particles of food decompose in the crevices with the formation of acids which soften the enamel. The handsome human chin, prominent and forming a decided angle, which is a measure, so called, of our determination, is the result of the more rapid shortening of the margin of the jaw bearing the teeth. The prognathous jaw of the Australian Bushman may not be a thing of beauty according to our standards of human beauty, but from the point of view of mouth hygiene, it is a consummation devoutly to be wished.

Other parts of the alimentary canal have lost their original function and to that extent have become liable to disease with all its consequences. Preeminent among useless parts of the alimentary canal is the vermiform appendix that has won an immortal fame through mortality due to inflammation of the little member. The anthropoid apes all have an appendix which is invariably longer than that of man. Its function in the human species, so far as our knowledge goes at present, is negative. In fact there are features of its embryonic development that would seem to indicate that it is simply one step in the reduction of the cæcum to which it is attached and which in like fashion is also undergoing further decrease in the human subject. The cæcum in herbivorous forms attains a large size and probably plays an important part in the digestion of the coarser parts of vegetable foods like cellulose. But in the human species, and as far as that is concerned, in the apes as well which have already begun to feed on more delicate foods including fruits and insects, this part of the alimentary canal has undergone considerable reduction. In the human subject the cavity of the cæcum is cut off completely from that of the rest of the alimentary canal in about twenty-five per cent. of the subjects examined.

On account of the relations of the appendix to the cæcum and intestine and its rudimentary character, the contents frequently stagnate and undergo decomposition so that infections are frequent which produce appendicitis.

Another portion of the alimentary canal which has lost its function to a greater or less extent is the large intestine or colon. Like the cæcum, the colon probably was originally important in completing the digestion of cellulose, which forms so large a part of the tissue of plants and which resists the action of the digestive juices. But in the human subject who, partly on account of the weakening of the teeth, does not eat cellulose in such large quantities, the colon has ceased to be an important organ of either digestion or absorption. It serves in the human largely as a reservoir for the indigestible portions of the food from which water is absorbed. The undigested food residues in the large intestine, particularly the rectum, decompose under the influence of countless bacteria which early in life find their way thither. The products of decomposition if allowed to remain in the colon are absorbed and produce the discomfort and inefficiency of constipation. Without a large intestine, no serious inconvenience follows, as shown by the cases of removal of that organ. There is one case recorded in medical literature of a French woman who lived a perfectly healthy and normal life for thirty years after the removal of the whole large intestine.

It is not only in the structure of different parts of the body that disharmonies may be found. Various functions of the body or reactions to stimuli may become perverted and work terrific damage on the individual and his progeny. It would be of great interest to analyze these disharmonies but the chapter is a long one and only one may be mentioned which has a physiological basis and which has deep significance in relation to the bacterial parasites. As is well known about one half of all the deaths are due to parasitic bacteria which gain entrance into the body and multiply and give rise to the poisons which in so many cases are fatal.

It would, however, be very misleading to leave the impression that there is no defense of the body against parasites like the pathogenic bacteria. In the course of evolution man has become protected against a large number of germs and has developed a number of defenses which stand him in good stead and without which it would be highly improbable that he could survive for long. For example, the layer of impervious, resistent, horny skin covering the whole body serves as a bulwark against the hordes of ever-present bacteria whose activities and readiness to attack are only too manifest when for any reason the integrity of the skin is broken as in a wound or surgical operation, when extreme precautions must be taken to prevent the entrance of living germs. Then, too, the respiratory tract including certain parts of the nose and the windpipe and bronchial tubes are lined with ciliated epithelium by which all particles which become embedded in the mucus secreted by intervening cells are swept outwards. Were it not for the protection thus afforded by the normal secretion of mucus and the constant sweeping of the cilia, infections of the lungs and respiratory tract would cause a far larger proportion of deaths than at present. The acid of the gastric juice also kills many bacteria which are taken into the stomach with the food and which would multiply rapidly in this otherwise ideal place for their multiplication. But the most important defenses against microbes are the so-called antibodies which are manufactured in the body and which either neutralize the poisons produced by parasitic bacteria or dissolve the germs after they gain entrance to the fluids of the body.

The human mechanism has scarcely begun to develop the antibodies which it is capable of producing, as is evidenced by the fact that man is susceptible to many diseases naturally but becomes immune under the stimulus of vaccines and viruses artificially administered, or the stimulus of an attack of the particular disease. The potentialities of the body in this direction are far beyond the actual accomplishments. What has been actually acomplished by means of the administration of antitoxin of diphtheria is indicated, for example, by the fact that mortality from this cause has been reduced from 50–60 per cent., to 12–14 per cent., by its use. Smallpox, plague, cholera, typhoid fever and a host of other diseases that have destroyed their legions, we know now can be prevented by the activity of the antibodies produced by the living human being under the stimulus of vaccines and sera. Thus a perfect immunity may be acquired under the stimulus of inoculation with anti-typhoid serum, as has been amply demonstrated in the army within the past few years. It is a matter of scientific knowledge that during the Spanish War, in 1898, every fifth man in our army of 107,000 was attacked with typhoid; but as a result of general vaccination against typhoid in the army at present, in 1916 on the Mexican border, out of 20,000 men only one man fell ill with typhoid in spite of the fact that it was prevalent in nearby towns.

This brief survey of the more obvious defects of human structure and function that put man at a striking disadvantage in contrast with some of his distant cousins who inhabit this earth ought perhaps to help us orient ourselves more perfectly in the universe. As a mechanism, man is far from perfect, but with his more perfect brain with its powers of logical reasoning and invention, he shows a capacity to adjust himself by the use of tools and other devices of his ingenuity to a rapidly changing environment, to defend himself against untoward circumstances and more than hold his own in competition with the other species of organisms on the earth to-day.

THE MECHANISM OF EVOLUTION

IN THE LIGHT OF HEREDITY AND DEVELOPMENT[1]

II

By EDWIN GRANT CONKLIN

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3. *The Germplasm Theory*

The germplasm theory of Weismann substitutes a simple and rational conception for this complicated and inverted view of development, heredity and evolution. According to Weismann the intrinsic causes of development are in the germplasm and not in the soma of the developed organism; the germplasm is continuous from generation to generation and is not made anew in each generation by the soma; the germplasm is relatively stable as compared with the somatoplasm, so that while the latter undergoes many changes in response to environmental stimuli, the former undergoes few. Heredity is the transmission of parental germplasms to offspring, usually through the male and female sex cells; ontogeny is the conversion of portions of the protoplasm into the differentiated tissues of the developed organism, while other portions remain unchanged, especially in the sex cells; evolution consists primarily in the transmutation of one type of germplasm into another, not of one type of developed organism into another. Thus at one stroke the germplasm theory, if accepted, eliminates most of the older theories of evolution and substitutes in the place of mysterious and even mystical causes relatively simple and mechanical ones.

Shortly after the publication in 1892 of Weismann's book on the "Germplasm" there was a general outcry against the highly speculative character of this theory. It was said that whereas genuine progress in science depends upon the control of the scientific imagination by the brake of observation and experiment, Weismann had allowed his imagination to run wild without any brake at all. One critic (Ryder) said that there

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 18, 1917.

was no more evidence for the existence of a germplasm separate and distinct from the body plasm than for the existence of "bowlegged hobgoblins on the back side of the moon," while another critic (Romanes) asserted that Weismann's analysis of the germplasm into units of seven different orders, such as *biophores, determinants, ids,* etc., had no more basis in reality than Dante's seven circles of the Inferno.

Nevertheless, in spite of the general outcry against it the germplasm theory is to-day more widely accepted than ever before and all recent work on heredity and evolution confirms the essential features of Weismann's theory. Relatively minor details of the original theory have been modified or abandoned as the result of further work, but its main foundations stand fast. Among the important confirmations of the germplasm theory

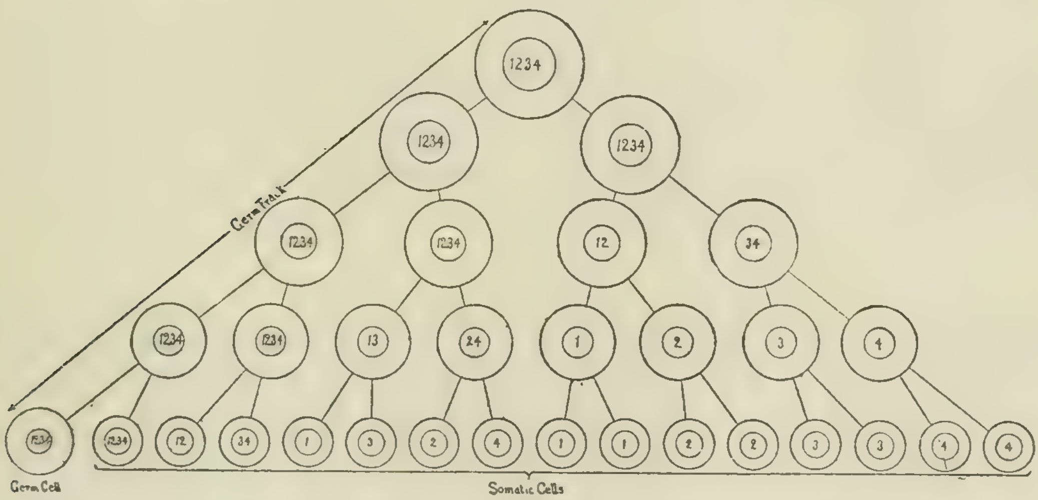

FIG. 9. *Diagram of the Mechanism of Ontogeny according to Weismann.* The determinants in the nucleus (1, 2, 3, 4) are supposed to be distributed differentially to the various somatic cells, whereas they are all found in the germ cells.

may be mentioned the great mass of work on Mendelian inheritance and germinal factors, while an important corollary of this theory is Johannsen's suggestive distinction of *Phenotype* and *Genotype,* the former being the developed type or soma, the latter the hereditary type or germplasm.

In one respect at least Weismann's theory was probably wrong and this was in the supposed manner in which the hereditary germplasm presides over development. Differentiation, according to Weismann, is caused by the disintegration of the germplasm, portions of it going into one cell and other portions into other cells, which cells differentiate into various kinds of tissue cells, depending upon the portions of the germplasm which they receive (Fig. 9). But there is no satisfactory evidence of

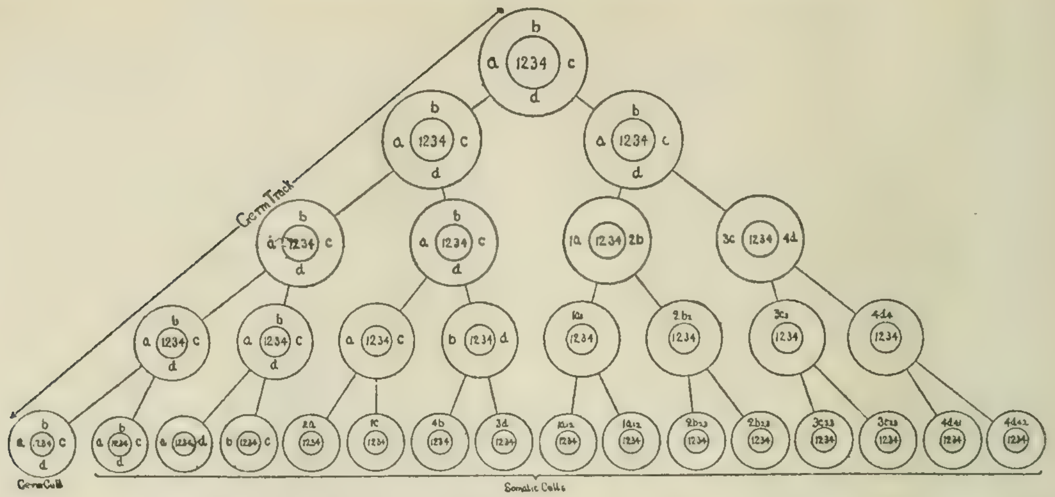

FIG. 10. *Diagram of the Mechanism of Ontogeny according to recent Workers.* The determinants or genes (1, 2, 3, 4) are distributed equally to every cell, but the cytoplasm is distributed differentially (segregation). The same determinants acting upon different cytoplasms produce different results in various somatic cells (new formation).

the qualitative division of the germplasm while the causes of differentiation may be explained in another way, as we shall see when we come to consider the mechanism of development, and as is indicated in Fig. 10.

Germplasm Identical with Chromatin, Somatoplasm with Cytoplasm.—The germplasm is not a mere logical abstraction; its distinctness from somatoplasm, its relatively great stability, its continuity from cell to cell, from generation to generation, from species to species are not unsupported hypotheses. We have within every cell two substances which possess these different qualities of germplasm and somatoplasm, as Hertwig, deVries, Roux, Weismann and many others have pointed out. There is convincing if not conclusive evidence that the germplasm is located mainly or entirely within the chromatin of the nucleus, while the somatoplasm, or that portion of the protoplasm which undergoes differentiation into the various structures, tissues, and organs of the developed body is the cytoplasm or substance of the cell body. Osborn (1915) accordingly calls the former of these the "heredity-chromatin," but it seems to me preferable to preserve the time-honored and familiar designations which have hitherto been used; accordingly in these lectures germplasm is thought of as located in or as identical with the chromosomes of the nucleus, while somatoplasm is located largely in the cytoplasm.

Not only is it possible to give the germplasm a cellular "habitation and a name," but it is possible to trace it from cell to cell, and from generation to generation and thus to establish its continuity; it is possible to show that the chromatin is more stable than the cytoplasm, that it comes in approximately equal quantities from both parents and that it is distributed equally to every cell of the developing organism; it is known that the quantity of this germplasm which goes into every mature egg or sperm cell is reduced to one half that found in the other cells of the body and that when egg and sperm unite in fertilization the normal quantity is again restored, and it is known that by means of this reduction and by the subsequent union of the sex cells in fertilization new combinations of germplasms are produced.

Through the work of Morgan and his pupils we are now beginning to understand something about what Weismann called "the architecture of the germplasm" and indications are at hand of the way in which this germplasm controls the differentiations of the egg and hence the development of inherited characters; and while we know little or nothing as to the precise manner in which the germplasm undergoes evolutionary changes no one acquainted with the evidence doubts that evolution can take place only through changes in the germplasm.

4. *The Causes of Development*

It is interesting and somewhat depressing to observe within what narrow limits the minds of men move in dealing with any great problem like that of the causes of development, whether of ontogeny or phylogeny. The modern investigator arrives at some conclusion which seems to him new and "epoch-making" only to find as he traces his discovery to its sources that it is merely a variant on some old, well-recognized theme, or in the language of modern biology a mere "fluctuation," and not a "mutation." There is nothing wholly new under the sun even in our theories, and yet there is development of ideas and evolution of theories. The outlines of the truth have long been known, but recent work has supplied many details.

Within the realm of scientific, that is of mechanistic, causation two general methods of explaining organic development, whether of a species or of an individual, have been proposed. The one finds the causes of such development in the environment, the other within the organism itself.

(*a*) *Environmental Causes of Development.*—Formerly great emphasis was placed upon the influence of environment in both ontogeny and phylogeny. The theory of epigenesis held that the distinctive causes of development were to be found in external forces and conditions rather than in the germ cells, which were supposed to be very simple in organization and practically without differentiation: and while no one now maintains, as St. Hilaire once did, that environmental conditions may determine whether an egg will develop into a reptile or a bird, it is still popularly supposed that stature is caused by the quantity and quality of food, sex by food or temperature, mentality by education, and that in general individual peculiarities are due to environmental differences.

From the earliest times it has been believed that one species might be transmuted into another by environmental changes and that even life itself might arise from lifeless matter through the influence of extrinsic conditions. The organism was regarded as being passively moulded by outside forces. Thus the theories of evolution of Buffon, Lamarck, St. Hiliare and to a certain extent of Darwin also were based upon the direct or indirect influence of environment in causing evolution. The sharp contrast which exists in certain respects between the two systems known as Lamarckism and Darwinism does not concern the influence or non-influence of environment in causing changes in organisms. Lamarck held that individual *adaptations* occur in response to environment and that these adaptations are inherited and thus become the building materials of evolution, but he did not attempt a mechanistic explanation of individual adaptations themselves. Darwin held that *variations* arise chiefly through changes in environment—"Variations of every sort," he said, "are caused by changed conditions of life"—unfavorable variations are eliminated by the environment while adaptive ones persist. Thus Darwinism offers a mechanistic explanation of adaptations, but it does not explain how changes in environment cause variations. The distinction between Lamarckism and Darwinism is to be found, therefore, in the manner in which adaptations are supposed to arise rather than in the causes of variation, for in both systems variations are usually attributed to environmental causes.

(*b*) *Intrinsic Causes of Development.*—Recent work on ontogeny and phylogeny places greater weight upon intrinsic than upon extrinsic factors in development. Modern studies of development have demonstrated the overwhelming importance of heredity as compared with environment; indeed it is doubtful whether environment serves in any other way than to hasten or retard, to stimulate or inhibit certain developmental responses of the organism, while the character and kind of response, the possibilities and limitations of development are determined by the organism itself.

In similar manner it is held by many geneticists that the distinctive or differential causes of evolution lie within the organism, and that environment plays a wholly subsidiary part. The real problem here is as to the causes of heritable variations, for it is universally recognized that these and these alone constitute the building materials of evolution. Certainly most of the variations which are caused by environment are not inherited and at present no unequivocal cases are known in which somatic variations caused by environmental change are known to be inherited.

Non-heritable variations are usually if not invariably caused by environmental changes, but many students of heredity maintain that heritable variations are always due to intrinsic or constitutional causes. Just as the constitution of the fertilized egg determines the nature of the organism which develops from it, so the constitution of the germplasm determines the nature of the heritable variations which arise from it. Davenport says, "As the egg develops into the complex adult with multitudes of differentiated cells, so primitive germplasm has developed into all present and past organisms." But this does not signify that everything which appears in the course of ontogeny or phylogeny was actually or "factorially" present in the egg or in the primitive germplasm. Development is not merely a "sorting-out process" but also a creative one. Everything which comes out of an egg or out of primitive germplasm was *potentially* in it or it could never have come out of it, but such an "explanation" of ontogeny or of phylogeny does not really explain anything. In similar manner it might be affirmed that the entire world, living and non-living, was *potential* in the material from which the world was made, without leaving us any the wiser.

Overemphasis upon the intrinsic causes of evolution and neglect of the extrinsic causes has led to the extreme view that elementary species, pure lines, unit characters or inheritance factors are immutable, except that in some instances they may undergo digressive changes like those of the radium atom, which changes are wholly independent of environment. According to this view "The foundation of the organic world was laid when a tremendously complex molecule capable of splitting up into a vast number of simpler vital molecules was evolved"

(Davenport, 1916), and evolution consists merely in "the unpacking of an original complex" (Bateson, 1914) so that it is a process of devolution, or simplification. According to this bizarre view, man would be, as Castle has said, "a simplified ameba." Such an extreme position is not unlike the "palingenesis" of Bonnet and might properly be called "natural creation" rather than "evolution," for as Caullery says, "there is no considerable difference between such views and creationist ideas."

(*c*) *Epigenesis and Endogensis.*—In the field of ontogeny no one now maintains the extreme view either of epigenesis or of preformation. The germ cells are not unorganized and wholly undifferentiated as Wolff maintained, nor do they contain a preformed organism as Bonnet taught. Development is not the creation of organization by outside forces nor is it the unfolding of an infolded organism.

> "We should look upon the germ as a living thing, and upon development as one of its functions. Just as the character of any function is determined by the organism, though it may be modified by environment, so the character of development is determined by heredity, that is by the organization of the germ cells, though the course and results of development may be modified by environmental conditions" (Conklin, 1915).

In similar manner most students of phylogeny maintain that evolution is the result of both extrinsic and intrinsic causes, of environmental and organismal factors. In the words of Darwin,

> "Although every variation is either directly or indirectly caused by some change in the surrounding conditions, we must never forget that the nature of the organization acted upon essentially governs the results."

(1) *Environment and Heredity.*—Differentiation and variation are conditioned by the organism and by the environment, by intrinsic and by extrinsic causes. In general the direction and character of individual development are determined by the organism, that is by heredity, while environment exercises a stimulating, inhibiting or modifying influence on the organism. It is altogether probable that the general factors of evolution are precisely the same as those of individual development, namely heredity and environment, and that their method of acting is the same, namely *the general direction and course of evolution is determined by the organism while environment serves merely as a stimulator, inhibitor or modifier.*

However, this contrast of organism and environment is by no means as simple and clear cut as is usually assumed. In many cases it is not only difficult to decide whether the differential cause of a character is one or the other of these, but it is even difficult to define what is meant by these two terms. The organism is not everything which lies within the skin and the environment everything outside of it, for much of the environment interpenetrates the organism without becoming a part of it. Moreover, there is an internal environment as well as an external one. Every organ, tissue or cell has its own environment in the surrounding body fluids and cells and this internal environment greatly influences the growth and development of every part. For example the development of many parts of the body depends upon internal secretions, such as enzymes or hormones, which act upon these parts as external environment acts upon the whole organism. At every stage in development the effects of external and internal environment are built into the organism and as one traces developed characters back to their earliest stages he realizes how difficult it is to separate these two sets of factors. And yet such a separation is at least *ideally* possible at every stage. We may say that the protoplasm represents the organismal factor, the non-protoplasmic substances the environmental. Possibly even protoplasm may be analyzed into a stimulating and a reacting portion, into environmental and formative substances, and this is indeed the view to which recent studies on the cellular basis of heredity have come. According to this view the protoplasm of the germ cells is not all equally concerned in inheritance, but a small portion of these cells, the chromatin, represents the hereditary organization, while the remaining portions act as innermost environment to this innermost organization. So far at least there is an actual basis in observation and experiment for separating hereditary and environmental factors, intrinsic and extrinsic causes, but whether such analyses can be extended to the different substances of which the chromatin is composed is at present unknown.

In this analysis into outer, inner and innermost environment and organization what are the distinguishing marks of the two sets of factors at every stage? Is it not that the intrinsic factor is in every instance the more specific one? In the same dish of water one egg will develop into a fish and another into a frog; the environment being the same in the two cases, the different results must be due to differences in the two eggs. Bathed in the same body fluids, one cell develops into muscle and another into nerve, owing to initial differences in the two cells. The same internal secretion in the blood affects different kinds of cells and different parts of the body differently, thus the internal secretion of the sex gland leads to the development of the most diverse secondary sexual characters in different parts of the body, depending upon the specific nature of the cells acted upon. Within a single cell different chromosomes have different peculiarities both of structure and function; one may be short, another long; one may be a factor in determining sex another in determining color, etc., and yet all of these chromosomes are surrounded by a common cell substance and are bathed in common fluids. In each of these instances both intrinsic and extrinsic factors are indispensable and practically inseparable, but the intrinsic factors are more specific than the extrinsic ones.

(2) *Structure and Function.*—As environment may be analyzed into outer and inner, so for convenience and effectiveness of treatment organisms may be studied from the standpoint of their structures or their functions, but a living thing consists of both structures and functions and in reality these can not be separated from one another. Failure to recognize this is due perhaps to the fact that after the death of an organism its functions cease to exist, but its grosser structures, especially those composed of non-living or formed material, persist for a time and are often referred to as if they constituted the whole organism. But the active, living structure is the formative material or protoplasm of the cells and it is certain that the structure of this is not the same in the living and in the lifeless condition. Confusion on this subject would be avoided if, instead of thinking of the structures of organisms or of organs as a whole, composed as they are of much formed material as well as of protoplasm, we should have in mind the structures and functions of the living substance only. As long as life lasts the structures and functions of protoplasm are both present and inseparable; neither functionless living structures nor disembodied functions exist in organisms.[3] A living thing is a system in action; it is matter and energy. When the action wholly ceases the system is dead; when the contained energy is liberated from coal or from protoplasm the remaining matter ceases to be coal or protoplasm. Function and structure are two aspects of one thing, namely, life; they are the obverse and reverse sides of the same coin.

It would be unnecessary to mention these very elementary truths were it not for the fact that so many persons have failed

[3] Rudimentary organs or structures may seem to negative this statement, but while such structures may lose or change their original functions they can never be said to have no function.

to appreciate their significance. From the time of Aristotle and Plato to the present many students of organisms have maintained that function is the cause of structure, as if a disembodied function could form a body around itself, as if digestion, or exertion or vision could exist apart from material bodies and then proceed to form a stomach or kidney or eye. Lamarckians generally hold that modifications of functions or habits cause modifications of structures, as if the change in function preceded the change in structure. But there is good reason to believe that every change in function is accompanied by a corresponding change in structure, and *vice versa.* Because of the fact that functional changes are more easily seen than structural ones a change of function may occur without any visible change of structure; but this merely means that physiological indicators are more delicate than morphological ones. We know, for example, that there are actual structural differences between the egg of a worm and that of a starfish, but these structural differences were not discovered until very recently, whereas the differences in the developmental functions of these two eggs have been known from the first. There are many bacteria which can be distinguished only by their functions; for example one will liquefy agar, another will not, one will ferment dextrose another levulose, etc., and yet there is no reason to doubt that there are corresponding structural differences between these forms which have not yet been seen. Different chemical substances are often recognizable only by their reactions and yet every molecule probably has its distinctive structure.

To attribute growth, differentiation or evolution to function rather than to structure is due merely to lack of clear thinking. No doubt functional activity is a most important factor in growth and development; the used muscle grows in size and power, the unused one remains undeveloped or even atrophies. But in the use of a muscle both structure and function are involved; some *thing,* some *structure* contracts and as a result receives increased nutriment, and there is coincident growth both of structure and function. The long neck of the giraffe has been attributed to its habit of browsing on trees, the long neck of the clam to its habit of deep burial in the mud. It is pertinent to inquire where these animals got these habits and indeed what habit consists in and whether changes of habits may occur without corresponding, though perhaps very minute, changes of structure.

On the other hand the morphological view of development and evolution regards structure as preceding function; changes in function or habit are held to be caused by changes in structure. This opinion was once widely prevalent among morphologists and yet it has no more foundation in fact than the opposite view; the fact is that both the functional and the structural views of development and of evolution are partial views caused by a too narrow consideration of organisms from one or the other standpoint. So far as we know neither function nor structure stands in a fixed *causal* relation to the other though each conditions the other. Instead then of maintaining as most evolutionists have done that function is the cause of structure or that structure is the cause of function, the biologist who can see life and see it whole recognizes that neither of these aspects of an organism can exist by itself and that neither is the cause of the other. Function is not primary and structure secondary, but both change and evolve together.

GROWING PLANTS AS HEALTH-GIVING AGENTS

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EVERY one of refined tastes admires, if he does not actually have a tangible interest in, growing plants and flowers. Plants and flowers have in all ages been highly prized for their beauty and sweet perfume, and they are utilized as the chief objects of ornamental decoration on all occasions of public festivity. The introduction of these elaborate decorations occurred about the year 1867 (so says the *Court Journal*) when Sir Edward Scott gave the first grand floral ball in Grosvenor Square. The order to a well-known florist was that he (Sir Edward) wished his to be the handsomest ball of the season, and that he would place his house in the hands of the florist for three days to do as he liked, regardless of expense. The decorations caused a perfect furore, and it was the means of entirely revolutionizing the style of artistic decorations, not only in London, but also in every part of the United Kingdom, and, indeed, the whole of Europe and America. Moreover, this pleasant innovation had the happy effect of proving for all future time an incentive to the more general cultivation of plants. It it most gratifying to be able to note that the popularity of the practise has been growing until the present time (although too slowly), shedding a beneficent influence upon the progress of social refinement.

In the light of modern investigation, however, it would surely be rash to continue to hold the once popular view that the main purpose of plants and flowers is to appeal to our sense of the beautiful as displayed in their varied colors and graceful forms. This statement will become clear to the mind of the reader, provided we shall be able to make good our promise to show that while remarkable for their beauty they are not less remarkable for their effects upon human health and welfare, or, in other words, to establish new and vital relations between vegetable growth and the human family.

From the highest antiquity many important material relations of the vegetable kingdom to man's various needs have been recognized. Further than to make mention of these as they affect either the productive resources of a region or the various domestic, artistic, and industrial purposes to which they are put, would be irrelevant to my present purpose. *Apropos* of the well-known metaphor "mother earth" it is to be recollected that the mineral kingdom is farther removed from us by one generation than the vegetable kingdom, hence we should naturally have a greater feeling of affection for the latter than the former.

It has been well said that the "fad" is an essential adjunct to every well-ordered life. Even the non-botanist will find a superficial study of wild flowers a satisfactory diversion for his vacation days and leisure hours. The plan offered in recent years by Chas. Lincoln Walton,[1] M.D., in his book styled "The Flower-Finder" is an excellent one for the purpose.

These days, the fact is pretty generally recognized, that all must work and all must play, or otherwise they grow stale or something worse. The largest measure of success in the application of this principle is to be attained by a study of needs of each individual, or classes of individuals. For example the mental worker not only requires systematic muscular activity in the open, but also relaxation for the mind, which must be diverted into other than the usual channels. For this large and important category the recreation exercise so easily obtainable in connection with the study and classification of wild flowers is to be earnestly encouraged and advised, as a means of meeting the mental phase of their requirements. The underlying principle involved quite properly assumes that a change of mind activities from the usual from time to time is essential to health and the highest degree of efficiency. Hence it is that the student of the classics or mathematics or a member of one of the three so-called learned professions—ministry, law and medicine—would find relief in the association with, and study of, growing plants and flowers. It is a splendid and effective method of inducing relaxation from the tension which will invariably tend to staleness if not in some way relieved. Indeed, this suggestion would be very helpful to all civilians.

Incidentally, the study of wild flowers necessitates considerable walking exercise. One can not ride and learn to recognize these beautiful specimens by the roadside and in field and forest, and after the love of exercise has been acquired, a brisk walk of a few miles, the while looking for and observing new

[1] "The Flower-Finder," J. B. Lippincott Co., by Chas. Lincoln Walton, M.D.

friends in the plant world, is a wonderful brace, stirring the blood, clearing the mind and strengthening the muscles,—in short it improves the vital, organic functions and prolongs life, not to speak of the enjoyment it affords. The method involves the observance of an important principle of hygiene, for in this pleasant pursuit of knowledge we incidentally acquire health, which is an asset of the greatest moment both from an individual and from a community viewpoint.

It is particularly desirable that a "fad" such as recommended above be adopted after the age of forty so as to ward off the degenerative diseases which are due to lack of physical exercise and overeating, and which have been steadily increasing in frequency of occurrence and mortality rate during the last quarter of a century. Again this statement applies especially to the dweller in cities, who has less chance than the dweller in the country to keep his body sound and vigorous. In this connection certain observations made by the late Theodore Roosevelt are pertinent:

> Any young lawyer, shopkeeper or clerk or shop-assistant can keep himself in good condition if he tries. Some of the best men who have ever served under me in the national guard and in my regiment were former clerks or floorwalkers. Why, Johnny Hayes, the marathon victor, and at one-time world champion, one of my valued friends and supporters, was a floorwalker in Bloomingdale's big department store. Surely with Johnny Hayes as an example, any young man in a city can hope to make his body all that a vigorous man's body should be.

The writer ventures to state that the sort of association with plant life recommended here would prove to be a revelation of a most agreeable character to the educated, and uneducated even,—in short to all whose attention has not been previously directed to its health-giving influence. He would especially urge heads of families to better the physical condition and in a measure secure the education of their children in this excellent manner. Moreover, this method of study would teach the young and rising generation to avoid temptations lurking in neighborhoods not conducive to good citizenship.

Perhaps one of the best fields in which to carry on these plant studies is offered by our public and secondary schools, as well as universities. The method would serve to widen the mental horizon of students and prove of decidedly stimulating interest apart from its great health-giving and moral value. These out-of-door educational and sanitary trips could be easily arranged for, by forming groups of pupils, in most towns and cities at least, and the tramps would be greatly enjoyed by all.

True it is that wherever found to be practicable students would soon show an ardent interest in this method of gaining instruction. The writer cherishes in memory wonderfully delightful trips of the sort.

It would be especially appropriate and convenient to arrange such expeditions for classes, or groups of older persons, during the summer vacation period and in connection with camp life. Their association with one another while enjoying intimate contact with elemental nature would lead to friendly ties, the while gaining useful information and healthful recreation. The method advocated would thus become a potent democratizing force.

There are also beneficial effects of growing plants and flowers of much importance due to their atmospheric influences. Until comparatively recent years (and in many quarters still) erroneous notions were entertained concerning the physiology of the vegetable kingdom. It must be confessed that the universal prejudice against plants and flowers in living and sleeping rooms which formerly existed is still exercising considerable sway over the more or less ignorant classes. There seems to be a deeply-rooted belief that plant respiration removes the oxygen from the surrounding atmosphere to such an extent as to be positively injurious when kept in living and sleeping rooms. They are also accused of giving off carbon dioxide to the same medium and thus rendering it deleterious when breathed. The carefully conducted experiments of Pettenkofer, however, have shown beyond all dispute, that the amount of oxygen absorbed from the air and the percentage of carbon dioxide exhaled as the result of plant breathing are too small to exert any appreciable effect. At all events, Pettenkofer's investigations indicate conclusively that no ill effects to the human race can be traced to the cultivation of plants and flowers indoors. It it strongly to be hoped that this statement will be given the widest publicity and also that it will be generally accepted. There are many lovers of growing house-plants and flowers, especially among women, but a not inconsiderable percentage of them do not cultivate these helpful and ornamental objects, owing to the unwarranted belief already mentioned that they are prejudicial to health.

It is an interesting and important fact that quite apart from the organic function of respiration, which proceeds uninterruptedly, and the harmlessness of which has been demonstrated, growing plants give off oxygen to the surrounding air in an amount sufficient to improve this medium by increasing its oxidizing properties. The sanitary advantage thus offered is not appreciated to an extent commensurate with its significance. The writer's experiments, conducted long since (and later confirmed by French observers), showed conclusively that flowering plants as well as all odoriferous foliage, *e.g.*, pine trees, possess the peculiar power to convert the oxygen of the air into ozone. The far-reaching importance of this fact can be only grasped when it is recollected that it is the ozone contained in the air which oxidizes, or in other words burns up, the various impurities to be found in this life-giving medium. If this be correct no argument is needed to prove the high sanitary value of blooming and odoriferous plants, especially when grown indoors.

It must not be forgotten that the companionship afforded by growing plants and flowers in living rooms and close proximity to the home is soon highly appreciated by those who take up floriculture, hence here we find another excellent reason why these objects of beauty and social instincts should not be neglected. Unquestionably, the greater our intimacy with the habits, classification, modes of fertilization and functions of plants and flowers the greater will be our love for them and also our sense of appreciation of their hygienic and esthetic values.

There is another phase of the physiology of growing plants and trees which indicates clearly that they exert a beneficent effect upon the salubrity of the surrounding air. I refer to the function of transpiration, or the evaporation of moisture from their leaf surfaces. The actual amount of water thus returned to the atmosphere is far in excess of what persons versed in vegetable physiology had supposed, when they came to note the actual results of carefully conducted experiments by the writer and others.[2] It has also been shown that soft, and thin-leaved plants show the most active rate of transpiration, and such as possess foliage of this sort should be selected so far as practical in making a choice for indoor cultivation. It has been computed that the Washington Elm at Cambridge, Mass., with its 200,000 square feet of leaf surfaces in twelve hours of clear weather transpires not less than seven and three fourths tons of vapor. Experiment clearly indicates that this function is a potent factor in maintaining a proper degree of moisture in the air, when plants are grown indoors. Verily, to plants may be assigned honorable rank as natural and efficient atomizers, making their influence everywhere felt beyond question.

[2] Vide "House-Plants as Sanitary Agents," by the writer, p. 93.

In this connection it should be borne in mind that the atmosphere of our artificially heated homes—and this is especially true of those all too numerous houses warmed by dry-air furnaces—is decidedly lacking in moisture. House-plants, rightly utilized, fulfil an important hygienic indication by adding moisture, and that freely, to these unwholesomely dry, usually overheated, and insanitary homes.

There can be no doubt that the public is taking more and more seriously, and rightly so, sanitary measures of all kinds. Certain deeply-rooted prejudices which are without foundation, however, can only be eradiated by time and oft-repeated demonstration. Perhaps one of the erroneous popular notions most tenaciously adhered to has been that house-plants are prejudicial to health, especially when grown in sleeping rooms, because of the ancient and fixed belief that they give off carbon dioxide during the night, rendering the bedroom unfit for breathing purposes during sleep. This notion has been successfully exploded, and, on the other hand, it has been clearly shown that this substance is constantly exhaled, that is to say by day as well as by night (plant-breathing), but in amount too minute to affect human health unfavorably. In view of the foregoing facts, growing house-plants and flowers which have considerable hygienic value owing to other functions, previously discussed, may be freely cultivated indoors, including bedchambers. Indeed among the numerous forms of diversion at our command, the practise of floriculture, which is neither difficult nor costly, should be held to be one of the foremost.

Here brief reference to two climatic influences of forest growth may be made. In the first place, trees possessing odorous foliage or flowers, especially pine grove forests, as was pointed out above in connection with plants grown indoors, increase the ozone or normal purifying agent of the external air. Again from facts developed as the result of experimentation, there can be little doubt but that forests tend to augment and maintain an equal degree of atmospheric humidity in their vicinity and in so far as this influence extends must they likewise tend to abridge the diurnal range of temperature—a matter of greater importance to the race than seasonal variations of temperature.

It has been well said by a recent writer, that a home which does not reflect the profusion of the outdoor season in the form of flowers in summer, is "as devoid of character and charm as a man without a necktie." For this purpose both cultivated and wild flowers in vases solve the problem. But if the desired object is to do something in the world to make men better, healthier and fitter for the duties of this life, we should advocate the cultivation of house-plants so that the people could enjoy their sanitary advantages as well as their beauty and delightful companionship. The thorough and searching investigations of the recent past have yielded results which should for all time afford pleasure and material benefits to all lovers of growing plants and flowers.

Moreover, association with these living objects develops an affinity which often results in genuine friendship. Indeed, contact with elemental nature has come to be recognized as a socializing and relaxing force of much importance. It will, however, require our incessant efforts at diffusion of a knowledge of this fact before it will be generally utilized or acted upon by the masses. It is high time to abandon the view so long dominant that an antagonism due to certain plant functions exists between the animal and vegetable kingdoms. It is equally in order to spread the gospel of health as it relates to the notable sanitary influences of growing vegetation, both indoors and out-of-doors and thereby encourage re-forestation and the cultivation of house-plants.

The only possible objection to growing house-plants is to be found in the heavy sweet odors given off by a few species, *e.g.*, irises and roses. These may give rise to headaches and other unpleasant symptoms in certain persons, but it is not necessary to include such examples in the selection of a group of plants for indoor cultivation.

Those who know what hygienic measures of this sort can mean to a community should carry the message to others who are less fortunate. The result of such a propaganda, we may be assured, would be an improved general state of health and a greater measure of human happiness. It is really inspiring to see the enthusiasm with which the men on whom the well-being of the race largely depends endeavor to make the fruits of their unselfish labors available by the dissemination of the needed information for health and happiness building. In growing plants and flowers, we have hygienic agents in such form as that their practical use need in no sense be circumscribed. They can be cultivated by rich and poor alike and hence floriculture should reach even the remote and obscure quarters of the earth. It would be an excellent and certain way of making home life everywhere increasingly more beautiful and healthful.

THE MICROSCOPIC IDENTIFICATION OF COMMERCIAL FUR HAIRS

By Dr. LEON AUGUSTUS HAUSMAN

(From the Zoological Laboratory, Cornell University)

THE use of the furry pelts of animals as articles of clothing is of very ancient origin, and probably contemporaneous with the beginnings of the manufacture of flint artifacts and war clubs. Its use as a decoration for the body, began presumably, somewhat later. The oriental peoples, as early as 2000 B.C. were using furs, not only as a protection against cold, but also as articles of luxury, and Herodotus mentions their use by other ancient peoples. Furs were much prized by the Romans, particularly during the later days of the empire, and the Saracens also made extensive use of them. It was from this latter source that the Crusaders first introduced furs into Europe, where they met with immediate favor, particularly among the nobles and clergy, where they were used in ceremonial regalia. The popularity of furs early rose to such a pitch that, in England and France, sumptuary edicts were issued against their unrestricted use, which did little, however, to check the increasing demand. It was to meet this demand that those hardy pioneers and explorers, the trappers and fur traders, penetrated far into the wildnernesses of the then unknown northern portions of North America, and established there the trading stations which later came to play such important rôles in the spread of the white man in America.

The use of furs as necessary articles of clothing as well as for ornamental purposes, is as great to-day as ever, and indeed during the past several years seems to have increased the severity of its demands. Certain mammals are being rapidly reduced in numbers, if not threatened with extinction; and certain furs are becoming rare and consequently expensive. Hence there arises the necessity for some methods whereby the species from which any given fur was obtained can be indubitably determined. For it is possible to remodel and rename furs, that is, so to clip, dye and pull them, that their original appearance is altered to such an extent that they may be sold under names not their own. Furs so remodelled may be sold under the names of furs much superior in wearing quality or in warmth.

Thus the pelts of animals from warmer zones such as the woodchuck (marmot), opossum, Australian opossum, raccoon, weasel, Tartar pony, Manchurian dog, and certain monkeys are worked up by fur dressers into articles but little resembling their originals and sold under other names, usually under the names of animals of northern latitudes. Such furs are inferior to those from colder climates in suppleness and durability of leather, denseness and silkiness of under, or fur-hair, fullness of over- or protective hair, and because dyed, brittle and less durable in general. One of the most durable of all furs is that of the sea otter (*Latax lutris*). Considering this to be represented by 100, the relative durability of some common furs, when used with the fur outside (not for linings), is as follows:[1]

Species	Durability (Otter = 100)
1. Beaver	90
2. Bear, black or brown	94
3. Chinchilla	15
4. Ermine	25
5. Fox, natural	40
6. Fox, dyed	20–25
7. Goat	15
8. Hare	05
9. Kolinsky	25
10. Leopard	75
11. Lynx	25
12. Marten (skunk)	70
13. Mink, natural	70
14. Mink, dyed	35
15. Mole	07
16. Muskrat	45
17. Nutria (Coypu rat), plucked	25
18. Otter, sea	100
19. Otter, inland	100
20. Opossum	37
21. Rabbit	05
22. Raccoon, natural	65
23. Raccoon, dyed	50
24. Sable	60
25. Seal, hair	80
26. Seal, fur	80
27. Squirrel, gray	20–25
28. Wolf	50
29. Wolverene	100

[1] Modified, from Peterson, "The Fur Trade and Fur Bearing Animals," Buffalo, 1914.

The misnaming of furs offered for sale in England reached, several years ago, such magnitude that the London Chamber of Commerce gave notice that misleading names were not to be employed, and that offenders were liable to prosecution. More definite legislation than now exists ought also to be had in this country. The following table[2] lists some of the best known furs, and their usual misnomers.

Species	Altered and Sold as
1. American sable	Russian sable
2. Fitch, dyed	Sable
3. Goat, dyed	Bear, of various kinds
4. Hare, dyed	Sable or fox
5. Kid	Lamb
6. Woodchuck (marmot), dyed	Mink, sable, skunk
7. Mink, dyed	Sable
8. Muskrat (musquash), dyed	Mink, sable
9. Muskrat (musquash), pulled and dyed	Seal, electric seal, Hudson Bay Seal, Red River seal
10. Nutria (Coypu rat), pulled and dyed	Seal, electric seal, Hudson Bay seal, Red River seal
11. Nutria (Coypu rat), pulled, naturall	Beaver, otter
12. Opossum, sheared and dyed	Beaver
13. Otter, pulled and dyed	Seal of various kinds
14. Rabbit, dyed	Sable
15. Rabbit, sheared and dyed	Seal, electric seal, Hudson Bay seal, Red River seal, musquash
16. Rabbit, white	Ermine
17. Rabbit, white, dyed	Chinchilla
18. Kangaroo (wallaby), various species, dyed	Skunk (marten)
19. Hare, white	Fox
20. Goat, dyed	Leopard

Up to the present time no very dependable series of criteria for the indubitable identification of mammal hairs was to be had. In a recent paper on the microscopic structure of mammalian hair[3] the author has pointed out that the constant characteristics of certain microscopic elements in the structure of the hair shaft are significant from several zoological viewpoints. That the results of the application of these criteria for the identification of commercial fur hairs may be of practical value

[2] Modified, from Jones, "Fur Farming in Canada" (Canada Commission of Conservation), Ottawa, 1914.

[3] Hausman, L. A., "A Micrological Investigation of the Definitive Hair Structure of the Mammalia, with Especial Reference to the Monotremata" (in press).

to the general public as well, it is the object of this paper to point out.

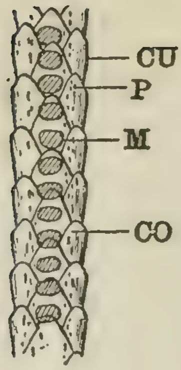
In order to appreciate the nature of the microscopic elements of the hair structure used in identification, it will be helpful to pass briefly in review the structure of the typical mammalian hair. Hairs arise from the bases of relatively deep pits in the epidermis, or outer layer of the skin, known as follicles, and push upward, being added to from the base, in a rod-like growth, of circular or elliptical cross section, and are composed of four elements (Fig. 1): (1) the *medulla* (*M*), or pith, consisting of many superimposed cells or chambers, which may be either separate or massed, (2) the *cortex* (*CO*), or shell, surrounding the medulla, of tough, horny, homogeneous texture and hyaline appearance, (3) the *pigment granules* (*P*), to which the color of the hair is primarily due, scattered about within the corticular substance, and (4) the *cuticle* (*CU*), or outermost integument of the hair shaft, lying upon the cortex and composed of plate-like scales, imbricated somewhat like the shingles on a roof. It is the form and interrelationships of these various structural elements, together with the diameter of the hair shaft, which form the series of determinative criteria to which reference has been made.

Medullas occur in four distinct forms: (1) the *discontinuous medulla,* as in the hair of the duck bill, or platypus, Fig. 27; (2) the *continuous medulla,* as in the hair of the red fox, Fig. 8; (3) the *interrupted medulla,* as in the hair of the hair seal, Fig. 13, which is a type intermediate between the first two; and (4) the *fragmental medulla,* as in the hair of the European otter, Fig. 11. It will be noted, furthermore, that the hair of some species lacks the medulla altogether.

The cortex, since it is usually of homogeneous structure, shows few or no compositional characteristics, and when used in description is merely measured as to thickness between the cuticle and medulla.

The pigment granules when present, are usually of characteristic form and distribution, and can often be used for one of the criteria for identification.

The elements, however, which presents the most readily usable and definite characteristics, are the scales of the cuticle. They fall into two great formal groups: (1) the *imbricate interrupted* type, those which lie singly imbricated about the hair shaft, like shingles on a roof, as in the hair of the Coypu rat, Fig. 18; and (2) the *imbricate coronal* type, those which



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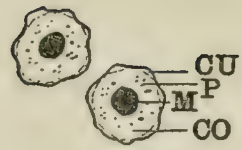

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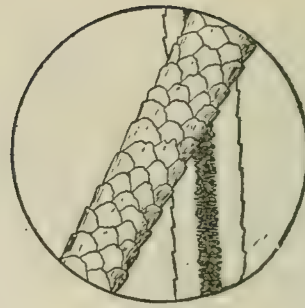

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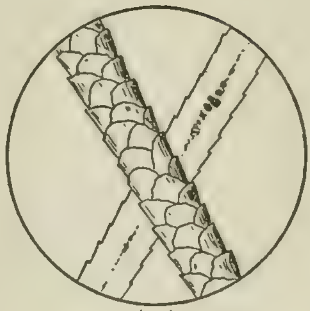

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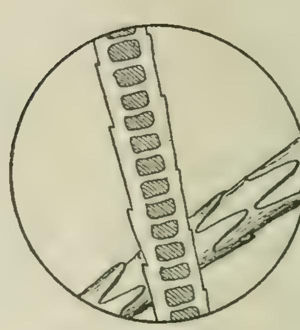

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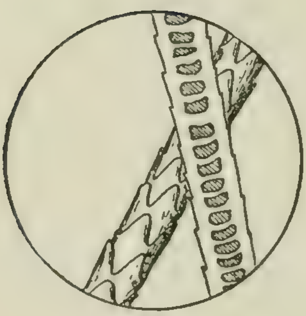

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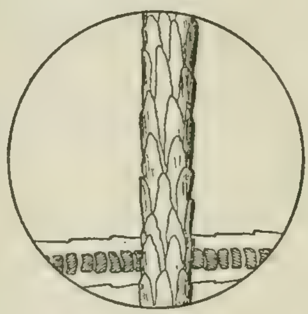

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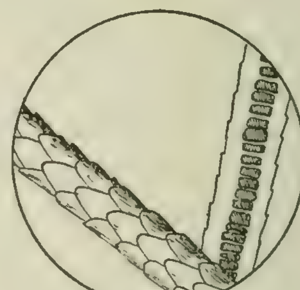

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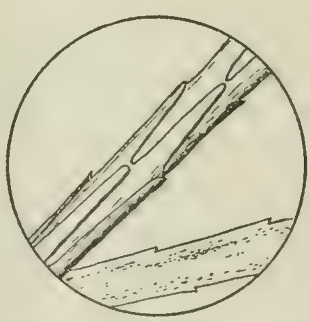

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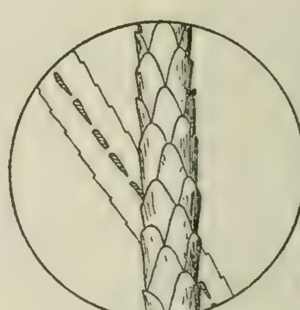

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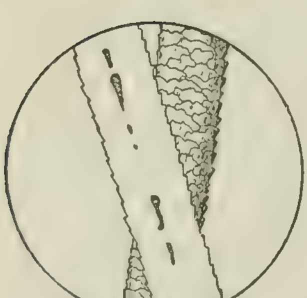

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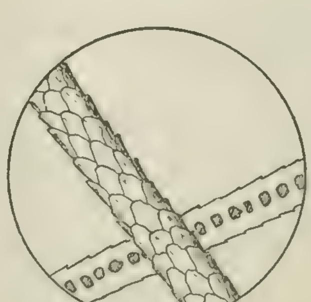

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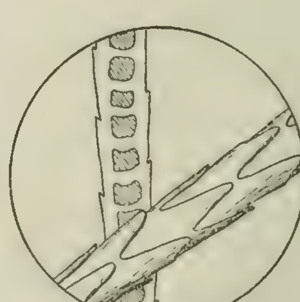

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encircle the hair shaft as continuous bands, as in the hair of the ermine, Fig. 6. Of these two types there are a multitude of intricate variations.

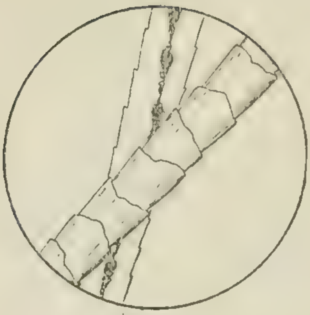
The hair covering of most mammals consists of two kinds of hair; a soft, thick, under hair, called the *fur hair*, and a longer, stouter hair, which overlies the fur hair, termed the *protective hair*. In commerce the names under hair and over hair are usually employed. Microscopic examination of the structures used for identification may be made, as is sometimes necessary, of both these kinds of hair. It is usually sufficient, however, to subject only the fur hair to examination.

The preparation of hair for ordinary examination is not laborious. Several hair shafts are taken, and washed in a solution composed of equal parts of 95 per cent. alcohol and ether, to remove any oily matter from their surfaces. They are then transferred to a clean glass slide; covered with a cover glass, and allowed to stand in a current of warm air until thoroughly dry. Examination can now be made directly, using the 8 x ocular and the 16 mm. and 4 mm. objectives. This simple treat-

FIG. 1. IDEAL GENERALIZED MAMMAL HAIR, TO SHOW THE STRUCTURE. *CU*, cuticle; *CO*, cortex; *M*, medulla; *P*, pigment granules.
FIG. 2. TRANSVERSE SECTION THROUGH TWO HAIR SHAFTS FROM THE DUCK BILL, OR *Platypus*. *CU*, cuticle; *CO*, cortex; *M*, medulla; *P*, pigment granules.

ORDER FERÆ (THE CARNIVORA)

FIG. 3. Badger (*Taxidea americana*), 57.
FIG. 4. Black bear (*Ursinus americanus*), various varieties of, 27.
European brown bear (*Ursus arctos*).
FIG. 5. Civet (*Arctogalidia fusca*), 21.
Domestic cat (*Felis catus*).
Wild cat (several species).
FIG. 6. Ermine (*Putorius erminea*), 17.
FIG. 7. Fitch (*Mustela putorius*), 18.
FIG. 8. Red fox (*Vulpes pennsylvanicus*), with its various varieties, 19.
Genet (*Viverra genetta*).
Kolinsky (see Siberian mink).
Leopard (*Felis pardus*).
FIG. 9. Canada lynx (*Lynx canadensis*), 19.
Marten (see skunk).
Pine marten (*Mustela martes*).
Stone marten (*Mustela foina*).
FIG. 10. Mink (*Putorius vison*), with its various varieties, 11.
Siberian mink (*Mustela sibirica*).
American otter (*Lutra canadensis*).
FIG. 11. European otter (*Lutra vulgaris*), 10.
Sea otter (*Latax lutris*).
FIG. 12. Raccoon (*Procyon lotor*), 20.
American sable (*Mustela americana*).
Russian sable (*Mustela zibellina*).
Fur seal (*Callhorinus ursinus*), and other species.
FIG. 13. Hair seal (*Otaria jubata*), 105. Sea lions of the genera *Eumentopias*, and *Zalophus* are also used.
FIG. 14. Skunk (*Mephitis mephitica*), 26.
FIG. 15. Wolverene (*Gulo luscus*), 25.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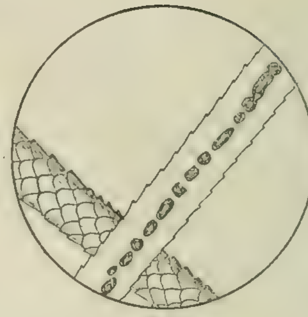
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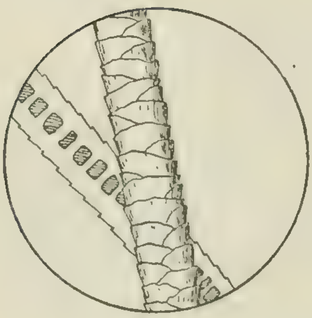
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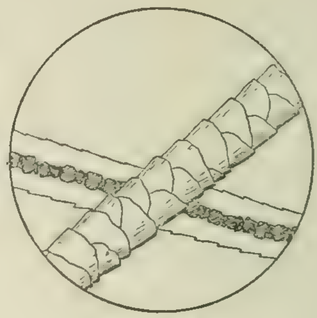
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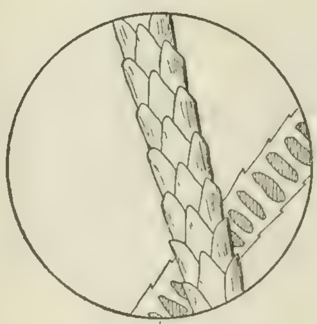
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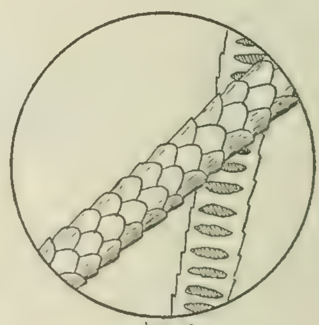
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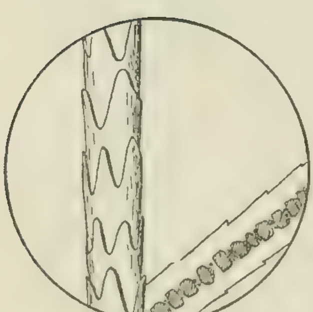
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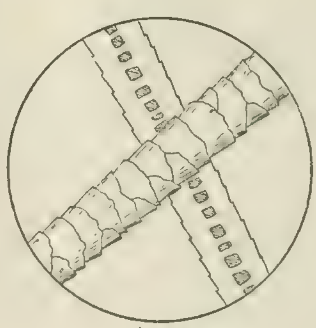
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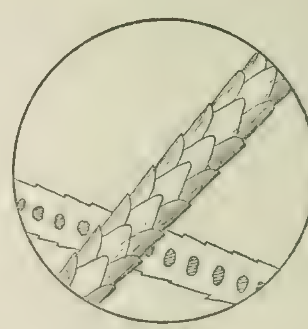
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ORDER GLIRES (THE RODENTS)

FIG. 16. American beaver (*Castor canadensis*), 18.
European beaver (*Castor fiber*).
FIG. 17. Chinchilla (*Chinchilla lanigera*), 16.
FIG. 18. Coypu rat, or nutria (*Myocastor coypus*), 11.
Cony (see rabbit).
Hare (*Lepus americanus virginianus*) and other species.
Marmot (see woodchuck).
Nutria (see Coypu rat).

ment answers very well for those hairs whose structural elements are large and prominent, such as those of the European otter, Fig. 11, and of the American beaver, Fig. 16. In other cases the hairs must be washed in the ether-alcohol as before, and then dipped with forceps into a 95 per cent. alcoholic solution of gentian violet, methyl blue, methyl violet, Bismarck brown, or safranin, of a degree of color depth which must be empirically determined for the best results with each different species of hair. This treatment renders clear the outlines of the individual scales. However, even this manipulation fails to reveal the contour of the scales of certain hairs, and various other methods devised by the writer, too lengthy for description here, must be called into service. Treatment with caustics, such as caustic soda or potash; or with acids, such as nitric or hydrochloric, which have sometimes been recommended, distorts the scales and thereby renders them valueless for delicate determinative purposes.

The treatments used to render the cuticular scales visible, obscure the medulla, hence other methods are necessary to bring into prominence this element of the hair structure. The simplest and most generally useful of these is to mount the hair on a slide in some one of the light oils used in micrological work, such as oil of cloves, oil of bergamont, oil of cedar, etc., after having washed the hair, as before, in the ether-alcohol solution. With some few hairs it is satisfactory to use clear water as the mounting medium. The methods used to bring the medulla into

FIG. 19. American gray squirrel (*Sciurus carolinensis*), 18.
Siberian gray squirrel (*Sciurus vulgaris*).
FIG. 20. Rabbit (*Lepus nutalli malurus*), and other species, 17.
FIG. 21. Woodchuck (*Arctomys monax*), 22.
FIG. 22. Muskrat (*Fiber zibethecus*), 17.

ORDER UNGULATA (THE HOOFED MAMMALS)

Domestic goat (*Capra hircus*).
Pony, or domestic horse.
Astrachan (*Ovis aries*), and its varieties.

ORDER INSECTIVORA (THE MOLES, SHREWS, ETC.)

FIG. 23. European mole (*Talpa europea*), 17.
FIG. 24. American mole (*Scalops aquaticus*), 17.

ORDER MARSUPIALIA (THE POUCHED MAMMALS)

FIG. 25. Koala (*Phascolarctos cinereus*), 22.
FIG. 26. Opossum (*Didelphys virginiana*), 37.
Rock wallaby (*Petrogala pencillata*).
Yellow wallaby (*Petrogale xanthopus*).

ORDER MONOTREMATA (THE EGG-LAYING MAMMALS)

FIG. 27. Duck bill, or platypus (*Ornithorhynchus anatinus*), 8.

clear visibility are also useful for rendering plain the pigment granules.

For the measurements of the diameter of the hair shaft, the ocular micrometer is perhaps the most satisfactory. Since, in any given tuft of hairs, there is considerable variation in the diameters of the individual shafts, the average of many measurements should be taken.

It was sometimes, though fortunately not frequently, found necessary to prepare transverse sections of the hair shafts, to determine more fully the contour of the medulla. Fig. 2 shows two shafts of the fur hair of the duck bill, or platypus, sectioned in this way.

In the following classified list are enumerated those mammals whose pelages are the most extensively used in the fur trade. The numbers against some of these, which are the most common, are the numbers of the figures wherein is shown the microscopic appearance of the fur hair. In each figure two hair shafts are depicted, one treated to show the cuticular scales; the other to show the medulla. The hair shafts are not drawn to scale; where there is so great variation in diameters this is not practicable. Hence, following the name of each species whose hair is figured, appears the average diameter of the shafts of the fur hairs, expressed in micra.[4]

[4] One micron 1/1,000 of a millimeter, or circa 1/254,000 inch.

THE REFLECTION OF LIGHT BY GRAVITATION AND THE EINSTEIN THEORY OF RELATIVITY[1]

By SIR JOSEPH THOMPSON,

PRESIDENT OF THE ROYAL SOCIETY IN THE CHAIR.

SIR FRANK DYSON, *The Astronomer Royal:*

The purpose of the expedition was to determine whether any displacement is caused to a ray of light by the gravitational field of the sun, and, if so, the amount of the displacement. Einstein's theory predicted a displacement varying inversely as the distance of the ray from the sun's center, amounting to 1″.75 for a star seen just grazing the sun. His theory or law of gravitation had already explained the movement of the perihelion of Mercury—long an outstanding problem for dynamical astronomy—and it was desirable to apply a further test to it. Many people considered it quite likely that, even if Einstein's conclusion was not confirmed, we should get half his computed deflection for a beam—this other result being the deflection of a particle moving past the sun with the velocity of light.

The effect of the predicted gravitational bending of the ray of light is to throw the star away from the sun. In measuring the positions of the stars on a photograph to test this displacement, difficulties at once arise about the scale of the photograph. The determination of the scale depends largely upon the outer stars on the plate, while the Einstein effect causes its largest discrepancy on the inner stars nearer the sun, so that it is quite possible to discriminate between the two causes which affect the star's position.

Previous eclipse photographs are generally unsuitable for evidence bearing on the point, as they are either on too large a scale showing too few stars on the plate or else on too small a scale to provide the delicate test with sufficient accuracy. The plates secured at Sfax in 1905 with one of the astrographic objectives used for the International *Carte du Ciel* seemed of suitable scale. Examination of them failed to give a definite result, but showed that this instrument was well suited to our

[1] From the report in *The Observatory*, of the Joint Eclipse Meeting of the Royal Society and the Royal Astronomical Society, November 6, 1919.

problem. A study of the conditions of the 1919 eclipse showed that the sun would be very favorably placed among a group of bright stars—in fact, it would be in the most favorable possible position. A study of the conditions at various points on the path of the eclipse, in which Mr. Hinks helped us, pointed to Sobral, in Brazil, and Principe, an island off the West Coast of Africa, as the most favorable stations, and the eclipse committee decided to send out expeditions to these two places if the war conditions allowed. Professor Turner, of the Oxford University Observatory, most kindly loaned the object-glass of the Oxford astrographic telescope, and the arrangements for mounting this and the Greenwich objective were pushed forward at Greenwich as hard as the reduced staff permitted. Father Cortie further suggested the use of a 4-inch lens of 19 ft. focal length belonging to the Royal Irish Academy. The instruments were assembled at Greenwich largely under Mr. Davidson's supervision, and all was ready in time for the observers to start from England in March.

The Greenwich party, Dr. Crommelin and Mr. Davidson reached Brazil in ample time to prepare for the eclipse, and the usual preliminary focussing by photographing stellar fields was carried out. The day of the eclipse opened cloudy, but cleared later, and the observations were carried out with almost complete success. With the astrographic telescope Mr. Davidson secured 15 out of 18 photographs showing the required stellar images. Totality lasted 6 minutes, and the average exposure of the plates was 5 to 6 seconds. Dr. Crommelin with the other lens had 7 successful plates out of 8. The unsuccessful plates were spoiled for this purpose by clouds, but show the remarkable prominence very well.

When the plates were developed the astrographic images were found to be out of focus. This is attributed to the effect of the sun's heat on the coelostat mirror. The images were fuzzy and quite different from those on the check-plates secured at night before and after the eclipse. Fortunately the mirror which fed the 4-inch lens was not affected, and the star-images secured with this lens were good and similar to those got by the night-plates. The observers stayed on in Brazil until July to secure the field in the night sky at the altitude of the eclipse epoch and under identical instrumental conditions.

The plates were measured at Greenwich immediately after the observers' return. Each plate was measured twice over by Messrs. Davidson and Furner, and I am satisfied that such faults as lie in the results are in the plates themselves and not in the measures. The figures obtained may be briefly summarized as follows: The astrographic plates gave 0″.97 for the displacement at the limb when the scale-value was determined from the plates themselves, and 1″.40 when the scale-value was assumed from the check-plates. But the much better plates gave for the displacement at the limb 1″.98, Einstein's predicted value being 1″.75. Further, for these plates the agreement between individual stars was all that could be expected. The following table gives the deflections observed compared with those predicted by Einstein's theory:

No. of Star	Displacement in R.A.		Displacement in Dec	
	Observed	Calculated	Observed	Calculated
11	− 0″.19	− 0″.22	+ 0″.16	+ 0.02
5	− 0.29	− 0.31	− 0.46	− 0.43
4	− 0.11	− 0.10	+ 0.83	+ 0.74
3	− 0.20	− 0.12	+ 1.00	+ 0.87
6	− 0.10	+ 0.04	+ 0.57	+ 0.40
10	− 0.08	+ 0.09	+ 0.35	+ 0.32
2	+ 0.95	+ 0.85	− 0.27	− 0.09

After a careful study of the plates I am prepared to say that there can be no doubt that they confirm Einstein's prediction. A very definite result has been obtained that light is deflected in accordance with Einstein's law of gravitation.

Dr. A. C. Crommelin, *Assistant Astronomer Royal:*

I have not much to add to what the Astronomer Royal has said, but I should like to say what a great debt we owe to the Brazilian Government for the immense help they gave us. Dr. Morize, the Brazilian national astronomer, gave all possible assistance; he had made a preliminary visit to Sobral a month before, when he made arrangements for our accommodation and also for supplying us with all the labor that we required—porters, bricklayers and carpenters were all freely put at our service. Members of Dr. Morize's staff helped by supplying us with chronometer errors and meteorological data. We were much indebted to Col. Vicente Saboya, the deputy for Sobral, who put his house at our disposal, with a permanent water-supply—no small boon in a time of drought, and of great importance in the photographic work. Dr. Locadio Aranjo, our interpreter, gave us invaluable help at every point, clearly explaining to the workmen our complicated demands, and calling the seconds for us at the eclipse. We were also indebted to the Booth Steamship Company for much help in dealing with our heavy baggage. They made arrangements with the local companies to forward it free of charge from Para to Camocim and thence to Sobral.

We should also thank the Sobral municipal authorities, who allowed us to encamp on the race-course and kept the public outside during the eclipse.

With regard to the bad focus of the plates taken with the astrographic during totality, we can only ascribe this to a change of curvature of the cœlostat mirror, due to the sun's heat; for the focus was good on the stars two days before the eclipse and again on the check-plates taken during July. The small cœlostat used with the 4-inch lens did not suffer from deformation, the images of stars during totality being of the same character as those on the check-plates; this increased the weight of the determination with that instrument. With regard to the July plates, we found that exposure was possible up to 25 minutes before sunrise, when the sky was of about the same brightness as during totality. 39½° was the greatest altitude of the field on the check-plates, as compared with 44° at the eclipse.

PROFESSOR A. S. EDDINGTON, *Royal Observatory:*

Mr. Cottingham and I left the other observers at Madeira and arrived at Principe on April 23. We were most kindly received at Principe by Sr. Carneiro. He also supplied us with all the labor and materials we needed, and we established our station at Sundy, the headquarters of his plantation, on the northwest side of the island. The island of Principe is about 10 miles long by 4 miles wide. We soon realized that the prospects of a clear sky at the end of May were not very good. Not even a heavy thunderstorm on the morning of the eclipse, three weeks after the end of the wet season, saved the situation. The sky was completely cloudy at first contact, but about half an hour before totality we began to see glimpses of the sun's crescent through the clouds. We carried out our program exactly as arranged, and the sky must have been a little clearer towards the end of totality. Of the 16 plates taken during the five minutes of totality the first 10 showed no stars at all; of the later plates two showed five stars each, from which a result could be obtained. Comparing them with the check-plates secured at Oxford before we went out, we obtained as the final result from the two plates for the value of the displacement at the limb $1''.6 \pm 0''.3$. The p.e. was determined from the residuals of individual stars. This result supports the figures obtained at Sobral.

There was one important difference in our data—we were unable to stay to take check-photographs of the field. As our eclipse took place in the afternoon, we should have had to wait some months longer than the Sobral observers to get the comparison-plates under the same conditions. We, however, took another field of stars for a check and compared our photographs with the Oxford plates of the same field to see whether a similar reduction gave evidence of any displacement corresponding to that found on the eclipse-plates. We got a very small value for the displacement on these check-plates, leading to the conclusion that the larger quantities found on the eclipse-plates could only be due to the presence of the sun in the field. We also used these check-plates to determine the difference of scale of the photographs at Oxford and Principe, and used that scale for working up the eclipse-plates. This was a great help in making the most of a small amount of material. A difference might have arisen for reasons of temperature changes; but the temperature at Principe is very uniform day and night—in fact, there was not 4° difference during the whole time we were at Principe, and we were there both for the hot and the cold season. Again, in one way we were helped by the clouds that at the time seemed so serious an obstacle; the sun's rays could not seriously affect the mirror by heating it, as seems to have happened at Sobral.

I will pass now to a few words on the meaning of the result. It points to the larger of the two possible values of the deflection. The simplest interpretation of the bending of the ray is to consider it as an effect of the weight of light. We know that momentum is carried along on the path of a beam of light. Gravity in acting creates momentum in a direction different to that of the path of the ray and so causes it to bend. For the half-effect we have to assume that gravity obeys Newton's law; for the full effect which has been obtained we must assume that gravity obeys the new law proposed by Einstein. This is one of the most crucial tests between Newton's law and the proposed new law. Einstein's law had already indicated a perturbation, causing the orbit of Mercury to revolve. That confirms it for relatively small velocities. Going to the limit, where the speed is that of light, the perturbation is increased in such a way as to double the curvature of the path, and this is now confirmed.

This effect may be taken as proving Einstein's *law* rather than his *theory*. It is not affected by the failure to detect the displacement of Fraunhofer lines on the sun. If this latter failure is confirmed it will not affect Einstein's law of gravitation, but it will affect the views on which the law was arrived at. The law is right, though the fundamental ideas underlying it may yet be questioned.

The difference of the two laws may be expressed analytically as follows: Any particle or light-pulse moves so that the integral of ds between two points of its path (in four dimensions) is stationary where

$$ds^2 = -(1-2m/r)^{-1}dr^2 - r^2d\theta^2 + (1-2m/r)\,dt^2 \text{ (Einstein's law).}$$
$$ds^2 = -dr^2 - r^2d\theta^2 + (1-2m/r)\,dt^2 \text{ (Newton's law).}$$

These expressions are in polar coordinates for a particle of gravitational mass m. I think the second expression may be accepted as corresponding to Newton's law—at any rate, it gives no motion of perihelion of Mercury and the half-deflection of light. What we have established is the necessity for the factor multiplying dr^2.

One further point must be touched upon. Are we to attribute the displacement to the gravitational field and not to refracting matter round the sun? The refractive index required to produce the result at a distance of 15′ from the sun would be that given by gases at a pressure of 1/60 to 1/200 of an atmosphere. This is of too great a density considering the depth through which the light would have to pass.

SIR JOSEPH THOMSON, *President of the Royal Society:*

I now call for discussion on this momentous communication. If the results obtained had been only that light was affected by gravitation, it would have been of the greatest importance. Newton did, in fact, suggest this very point in the first query in his "Optics," and his suggestion would presumably have led to the half-value. But this result is not an isolated one; it is part of a whole continent of scientific ideas affecting the most fundamental concepts of physics. It is difficult for the audience to weigh fully the meaning of the figures that have been put before us, but the Astronomer Royal and Professor Eddington have studied the material carefully, and they regard the evidence as decisively in favor of the larger value for the displacement. This is the most important result obtained in connection with the theory of gravitation since Newton's day, and it is fitting that it should be announced at a meeting of the society so closely connected with him.

The difference between the laws of gravitation of Einstein and Newton come only in special cases. The real interest of

Einstein's theory lies not so much in his results as in the method by which he gets them. If his theory is right, it makes us take an entirely new view of gravitation. If it is sustained that Einstein's reasoning holds good—and it has survived two very severe tests in connection with the perihelion of Mercury and the present eclipse—then it is the result of one of the highest achievements of human thought. The weak point in the theory is the great difficulty in expressing it. It would seem that no one can understand the new law of gravitation without a thorough knowledge of the theory of invariants and of the calculus of variations.

One other point of physical interest arises from this discussion. Light is deflected in passing near large bodies of matter. This involves alterations in the electric and magnetic field. This, again, implies the existence of electric and magnetic forces outside matter—forces at present unknown, though some idea of their nature may be got from the results of this expedition.

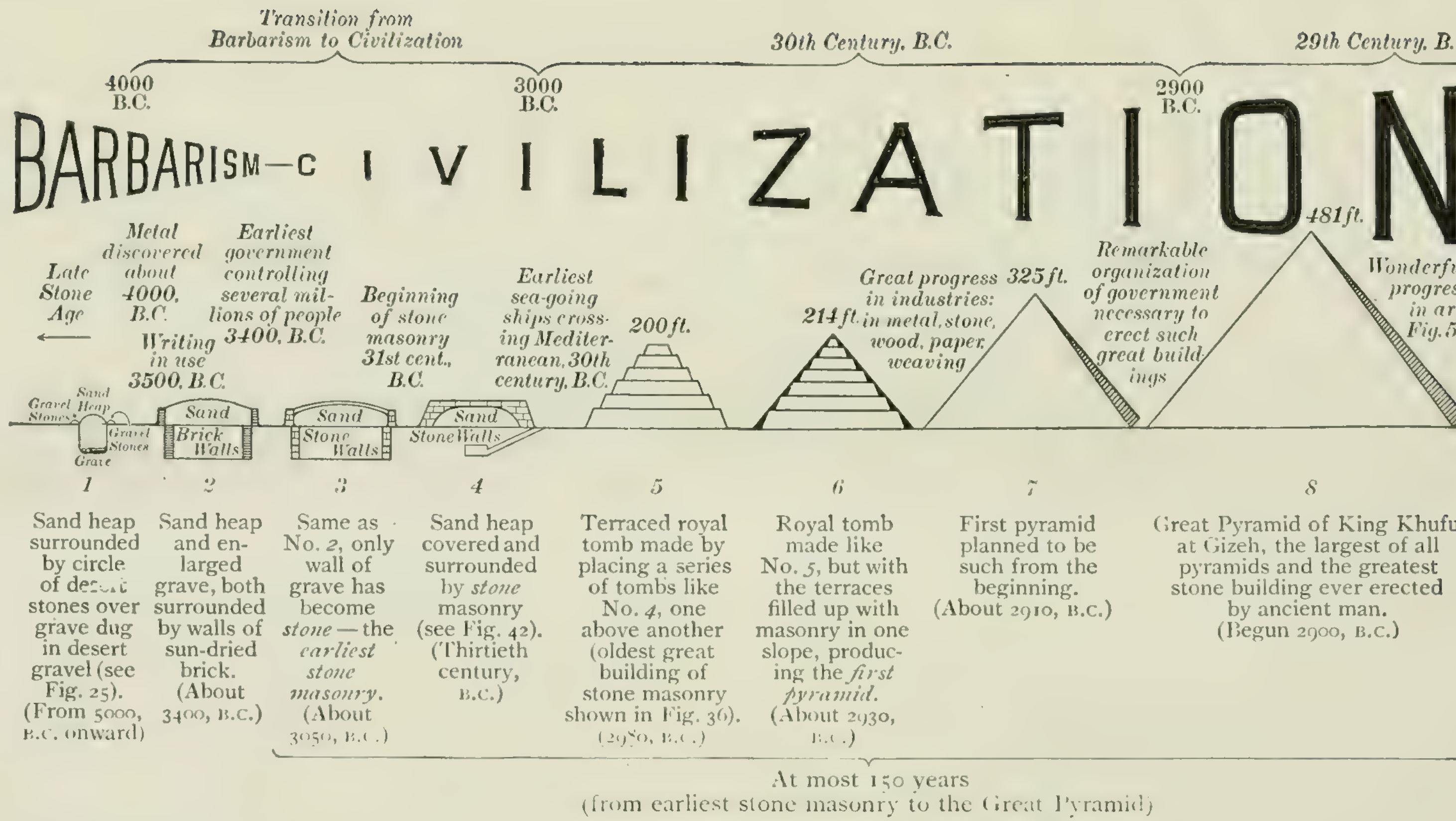


FIG. 65. DIAGRAM SHOWING THE EVOLUTION OF THE EGYPTIAN TOMB FROM THE SAND-HEAP TO THE PYRAMID. From the author's "Ancient Times," by permission of Ginn & Co.)

The body of the early Egyptian peasant lay at the bottom of a grave above which was a low heap of sand surrounded by a circle of rough desert stones to keep the sand in place. No. 1, above, shows this grave, cut down through the middle to expose the inside with the sand heap above it. In nos. 2, 3 and 4 we see the later tombs, also cut down through to expose the inside. They show how the circle of stones around the sand heap was slowly improved till it became real walls, first of brick (no. 2) and then of stone masonry (no. 3) enveloping the whole tomb, with the old sand heap still in the inside. Tombs like no. 4 were then placed one above the other, producing a tapering terraced building (no. 5) which was soon improved until it became a pyramid (no. 6). Thus the sand heap and its circle of stones were the germ out of which the mighty pyramids grew in the course of fifteen or twenty centuries. Notice how this wonderful growth in the art of building began with the sand heap in the barbarism of the Late Stone Age and thus carries us over from barbarism to civilization in the thousand years from 4000 to 3000 B.C. This great art of building was itself one of the things which marked the entrance upon civilization, and architecture passed from the earliest example of stone masonry to the Great Pyramid in only one hundred and fifty years. But incoming civilization was not marked only by progress in the art of building. The remarks inserted above, over the tombs and pyramids, suggest to us some of the other important achievements which helped to bring in and develop civilization, like the discovery of metal and the invention of writing, followed by the earliest government of a large population, the earliest seagoing ships, great progress in industries, and a remarkable development in art. We now see how the pyramids and their predecessors stand like milestones marking the long road by which man passed from barbarism to a highly developed civilization.

THE ORIGINS OF CIVILIZATION[1]

By Professor JAMES HENRY BREASTED

THE UNIVERSITY OF CHICAGO

LECTURE TWO

The Earliest Civilization and Its Transition to Europe

We have seen how the Stone Age hunters of the Nile gradually gained agriculture, domestic animals, metal, writing and industries, and leaving behind the men of the Mediterranean world elsewhere, in the thousand years between 4000 and 3000 B.C. transformed their northeast African game preserve into the first great state, regulated and controlled by a highly organized administration. This progress and especially its culmination in the thirtieth century B.C. is graphically visualized in the diagram in Fig. 65.

No. 1 at the extreme left end represents the pit grave, the only type of burial known until nearly 4000 B.C., which we saw in the first discussion. Surmounted by a low mound of sand, with perhaps a circle of stones around it, this earliest burial was the germ of the pyramid of stone masonry. We can trace the development from stage to stage—a development slow and gradual as civilization arose between 4000 and 3000 B.C., but quickening with surprising swiftness after passing 3000, that is during the thirtieth century, between 3000 and 2900 B.C. Hardly more than a generation before this thirtieth century the first example of hewn stone masonry was laid, and in the generation after this thirtieth century the Great Pyramid of Gizeh was built. With amazingly accelerated development the Egyptian passed from the earliest example of stone masonry just before 3000 B.C. to the Great Pyramid just after 2900. The great-grandfathers built the first stone masonry wall a generation or so before 3000 B.C., and the great-grandsons erected the Great Pyramid of Gizeh, within a generation after 2900. It will be seen that this development falls chiefly in the century between 3000 and 2900 B.C., that is the thirtieth cen-

[1] Delivered before the National Academy of Sciences in Washington, D. C., April 28 and 29, 1910, as the seventh series of lectures on the William Ellery Hale Foundation.

FIG. 66. TERRACED TOMB STRUCTURE OF PHARAOH ZOSER AT SAKKARA, EGYPT. The oldest known superstructure of stone,—built by the architect Imhotep (30th century B.C.).

tury B.C., which for this reason occupies more space in the diagram than the thousand years which precede it. No century in the history of man, except the nineteenth century of our era, has witnessed as rapid an expansion of man's control of material forces as the thirtieth century B.C.

It is therefore of great interest to contemplate the most revolutionary monument of that revolutionary century, the earliest stone building in existence (Fig. 66). This monument marks definitely the transition from sun-dried brick to stone masonry. It was erected as the tomb of King Zoser of the Third Dynasty, by his chief physician and architect Imhotep. This great man, the first builder of monumental architecture in stone, is little known, his fame having been rather groundlessly shifted to King Solomon by our friends, the modern Free Masons. Nevertheless we should not forget that he was the first builder to put up a great superstructure of stone 200 feet high, which still survives as the earliest stone building in existence. Imhotep's fame as a physician has eclipsed his reputation as an architect. He became the Asclepias of the Greeks, the Æsculapius of the Romans, and thus passed into the great company of the ancient gods.

The vast cemetery buildings which followed Imhotep's introduction of stone masonry superstructures reveal to us the first great civilized age of human history, an age to which these structures have given their name, so that it is commonly called the Pyramid Age. It lasted nearly 500 years from a little after 3000 to a little after 2500 B.C. The monuments and cemetery buildings of Gizeh are the monumental expression of the capacity of the first great state in human history.

They suggest a vista never to be forgotten. Out along the desert margin (Fig. 67) is many a grave of the prehistoric Egyptian peasant. The low sand or gravel heap, which once marked it, is the lineal ancestor of the vast monuments of Gizeh, the most tremendous feat of engineering ever achieved by ancient man. What a development is here! Not merely a development in the mechanical arts, which beginning with the sand heap have at last achieved the pyramid, but also a development in the organization of government and society, which slowly advancing in the thousand years or more which lie between the sand heap and the pyramid, has gradually passed from the feeble initiative and limited powers of the individual to the elaborate capacities of a highly organized state, so efficient that it is able with unerring precision to concentrate all

FIG. 67. THE CEMETERY OF GIZEH SEEN FROM AN AEROPLANE. These pyramids are the tombs of the kings and royal ladies of the Fourth Dynasty (about 2900 to 2750 B.C.). They are surrounded by the massive rectangular masonry tombs or "mastabas" of the nobles and officials of the same period. (Copyright by Moussault, N. Y.)

its vast resources of wealth and labor and mechanical skill upon one supreme achievement never later to be surpassed.

The Great Pyramid of Gizeh (Fig. 68) is the most impressive surviving witness to the final emergence of organized man from prehistoric chaos and local conflict, for it discloses him to us as he comes for the first time completely under the power of a far-reaching and comprehensive centralization effected by one all-controlling sovereign hand. Not the least remarkable aspect of this State is the sovereign's confidence in its efficiency. Here is a tomb containing 2,300,000 blocks of limestone, each weighing about two and a half tons, the assembling and erection of which in this building required the labor of one hundred

FIG. 68. THE GREAT PYRAMID OF GIZEH, THE TOMB OF THE PHARAOH KHUFU (CHEOPS), BUILT IN THE TWENTY-NINTH CENTURY B.C. It is the largest stone superstructure ever erected whether in ancient or (except recently) in modern times.

thousand men for some twenty years. Consider the daring imagination which could look out over this plateau, when it stood bare and empty, before its occupation by this building, and measuring off a square containing thirteen acres dared to begin covering it with a pile of stone masonry nearly 500 feet high. What must have been the mental quality of a man whose great-grandfathers had put together the first piece of stone masonry, and whose grandfathers had put up the first stone superstructure—what must have been the mental quality of a ruler who dared to plan and undertake a tomb of such colossal proportions that no such structure ever later attempted has approached it in size or in quality of workmanship! Such considerations give us an impressive measure of the Pharaoh's confidence in the efficiency of his administrative machine.

He must likewise have had great confidence in the ability of his builders to meet the difficult problems which at once confronted them as they mounted the Gizeh plateau and began laying out the ground plan of the vast royal tomb which they were called upon to erect. One finds it difficult to imagine the feelings of these earliest architects, the great-grandsons of the men who had laid the first stone masonry, as they paced off the preliminary plan and found an elevation in the surface of the desert which prevented them from sighting diagonally from corner to corner and applying directly a well-known old Egyptian method of erecting an accurate perpendicular by means of measuring off a hypotenuse.

It is evident, however, that the Egyptian engineers early learned to carry a straight line over elevations of the earth's surface, or a plane around the bends of the Nile. In his endeavor to record the varying Nile levels in all latitudes the Egyptian engineer was confronted by nice problems in surveying even more exacting than those which he met in the Great Pyramid. A study of the surviving nilometers has disclosed the fact[25] that their zero points, always well below lowest water, are all in one plane. This plane inclines as does the flood slope, from south to north. The Pharaoh's engineers succeeded in carrying the line in the same sloping plane, around innumerable bends in the river for some seven hundred miles from the sea to the First Cataract. It is not surprising in view of the difficulty of the feat, accomplished as it necessarily was with primitive instruments about which we know nothing—it is not surprising under these circumstances, that although they kept their line in one plane, they did not succeed in establishing the slope of their line exactly parallel with the flood slope. Later, however, when they extended this line up river they succeeded in carrying it very closely parallel with the flood slope for some two hundred miles further southward to the Second Cataract.

The builders of the Great Pyramid were therefore already in possession of the methods which enabled the Pharaoh's engineers to lay out a seven-hundred mile line of nilometers in one plane. The sockets cut into the limestone surface of the desert

[25] L. Borchardt, "Nilmesser und Nilstandsmarken."

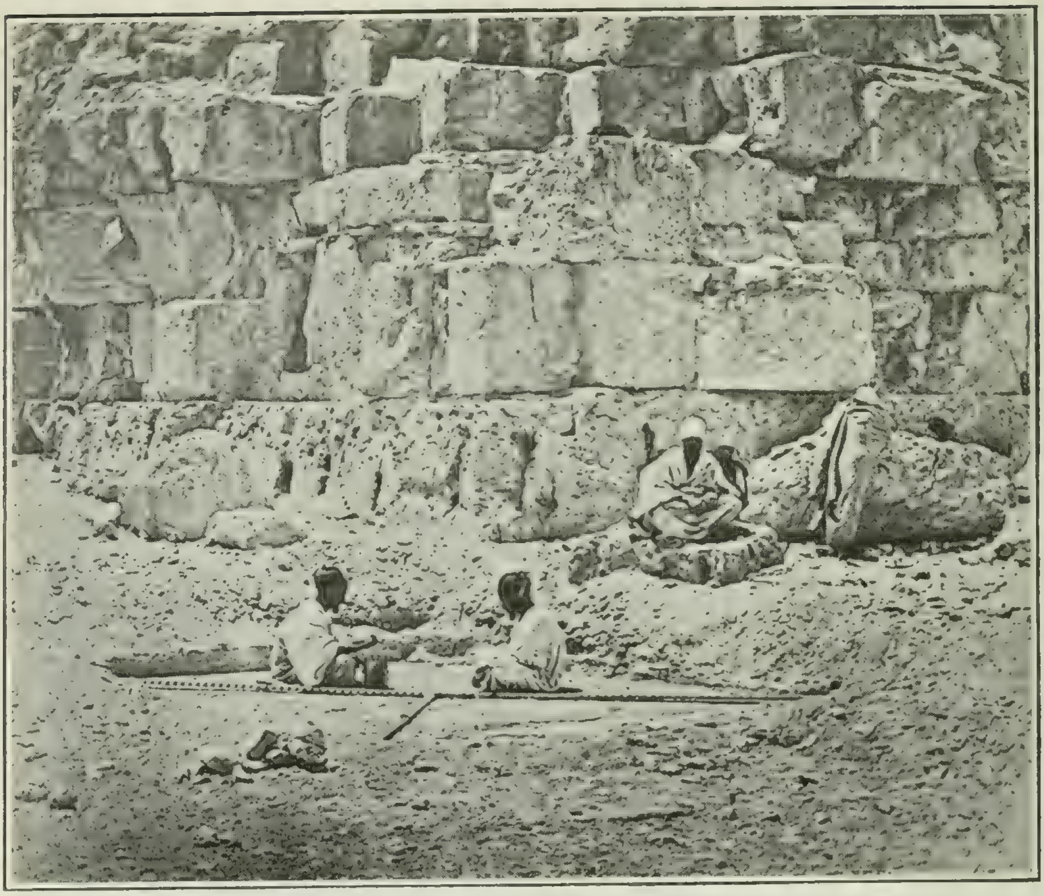


FIG. 69. RECTANGULAR SOCKET CUT IN THE NATIVE ROCK UNDERLYING THE GREAT PYRAMID. In this socket the northeast corner-stone of the building was laid; it was carried off by the Moslems.

plateau in which the cornerstones of the Great Pyramid were laid, still survive (Fig. 69), though the cornerstones themselves have been quarried out by Moslem vandals. These sockets enabled Petrie to establish the length of the sides as 755 feet. The maximum error he found to be .63 of an inch, that is less than one fourteen-thousandth of the total length of the side. The error of angle at the corners he found to be 12″ of a degree, that is one twenty-seven-thousandth of the right angle which the architect had laid out at the corner.

It is not a little interesting to follow the methods by which an agricultural people in a few generations developed the power to manipulate such vast masses of architectural materials as the Pharaoh's architects were then called upon to rear nearly 500 feet above this ground plan. The ruins of other pyramids and a pyramid left in an unfinished state at Gizeh have revealed much of the process of construction. Sun-dried brick ramps which were built higher as the pyramid rose, furnished an inclined plane up which the stone blocks were dragged by main strength on wooden sledges. Just how each block was shifted from the sledge to its particular place in the structure is still uncertain; for the description of the device for this purpose left us by Herodotus is not clear. The indications now are that the pulley-block was already available, but it is unlikely that its ability to multiply power was understood. After the completion of the building the ramps were taken down (Fig. 70).

The most remarkable feat of engineering involved in the erection of the Great Pyramid is probably the construction chambers rising in a series over the sepulcher chamber (Fig. 71). We have here a series of five roofs, the lowest built of granite blocks about twenty-seven feet long, six feet high and over four feet thick. They weigh some fifty-four tons each. After being quarried at the First Cataract these heavy blocks were brought six hundred miles down the river, dragged up to the plateau and then up the brick ramps to a level perhaps two hundred feet above the pavement, where they were so laid that they might protect the burial chamber from being crushed in by the weight of more than two hundred vertical feet of masonry rising above it. The principle which the pyramid engineers seem to have had in mind, was a mistaken one. They seem to have thought that if the topmost granite roof gave way, it was a good thing to have another ready just below it. The series of granite roofs is therefore of purely contingent value. They are crowned however, by a wiser construction of enormous limestone beams, an arch in principle but in appearance a peak roof. These vast

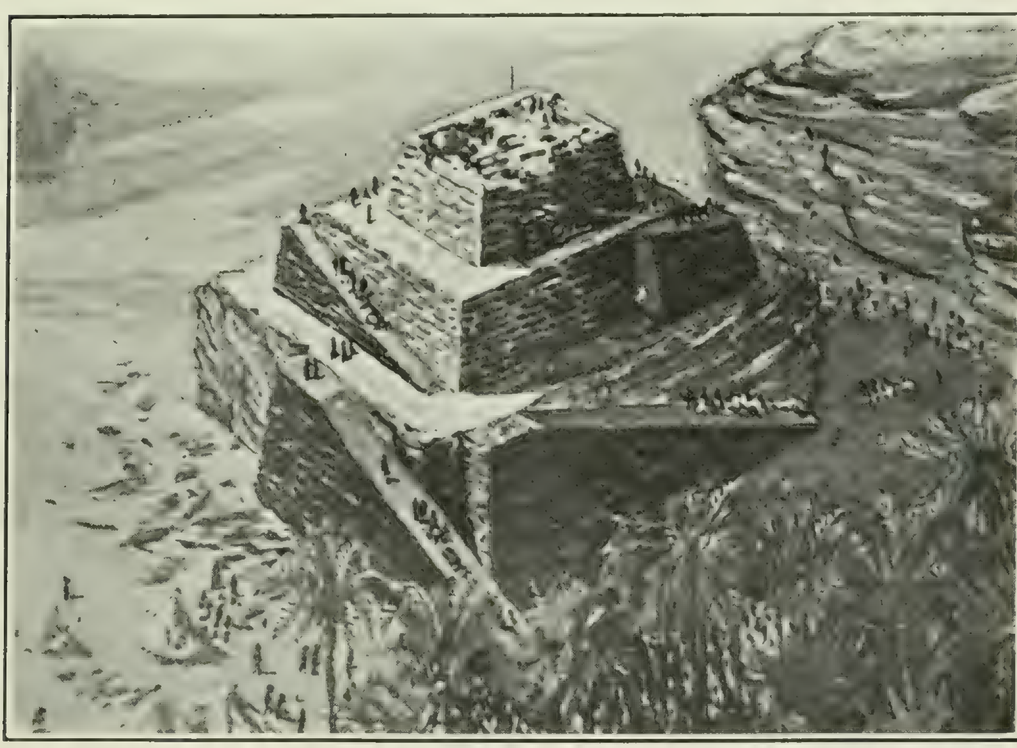


Fig. 70. Unfinished Pyramid at Gizeh, showing Sun-dried Brick Ramps for carrying up Building Material. (Restored after Hoelscher.)

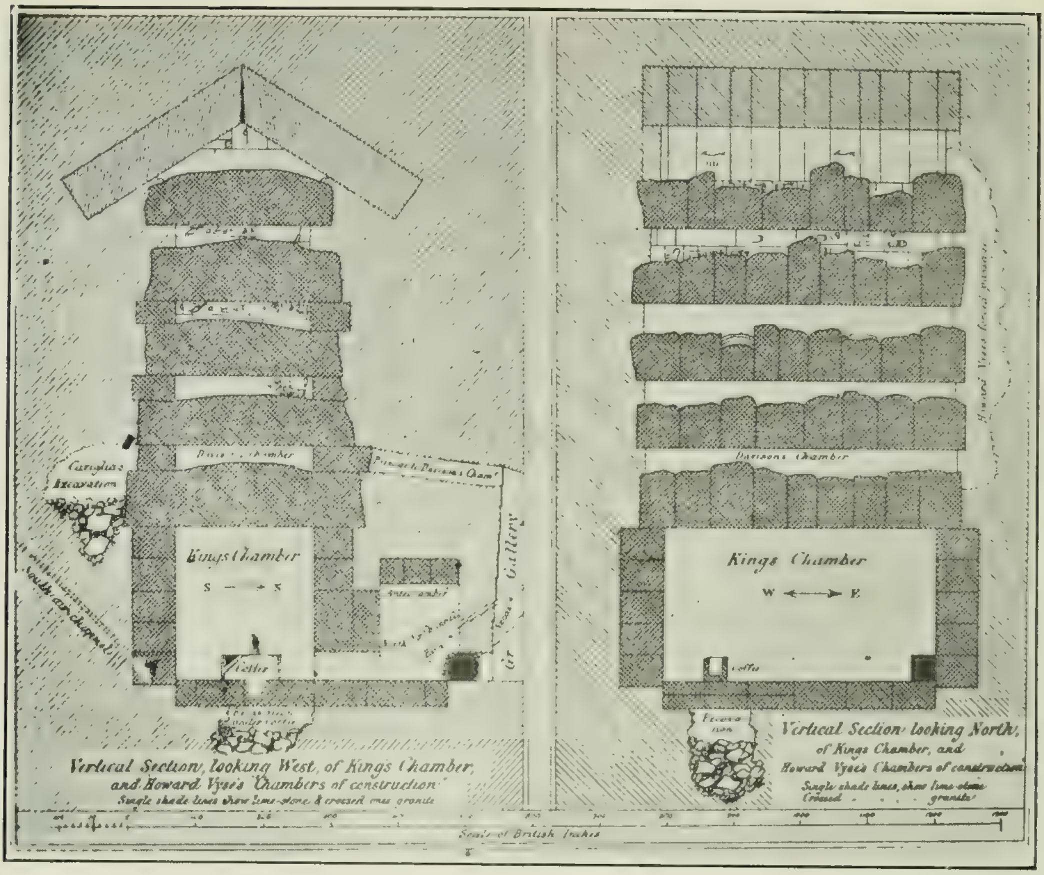


FIG. 71. SEPULCHRE CHAMBER IN THE GREAT PYRAMID OF GIZEH. Showing five precautionary construction chambers above it intended to carry the vast burden of the overlying masonry.

beams of limestone receive the colossal burden on their peak, and by their sideward thrust transfer it to the core masonry of the pyramid on each side of the sepulcher chamber, and thus save the roof of the latter from being crushed in. The effectiveness of the structure is strikingly brought out by the fact that although the beams of the horizontal granite roof immediately over the burial chamber have been broken short off entirely across the chamber by an ancient earthquake, nevertheless the contiguous ends of the beams on each side of the fracture have hardly settled perceptibly.

The ponderous mechanics of which the pyramid engineers were master is impressively illustrated by the enormous mass of stone chips produced by the army of stone-cutters who wrought 2,300,000 two-and-a-half ton blocks of limestone for the pyramid masonry. The accumulation of this rubbish had to be disposed of, and the foremen had it carried to the edge of the plateau and shot over the face of the cliff where it still lies at the angle of rest. It is equal in bulk to about half of the mass of the pyramid itself.[26]

[26] The best survey of the Great Pyramid has been furnished by Petrie, "The Pyramids and Temples of Gizeh," to which the above discussion is much indebted.

The industrial ability of the Nile-dwellers, which we found advancing so rapidly in the Early Dynasties, had in no way lagged behind the extraordinary engineering capacity which we have just been noticing. The skilful craftsmanship displayed in the cutting of the blocks for the Great Pyramid was certainly not to be expected from men whose great-grandfathers had laid the first stone masonry. The rough core masonry forming the present exterior of the building (Fig. 68) was originally sheathed in a magnificent cuirass of casing masonry extending from summit to base. Only a few blocks of this casing still survive along the base on the north side of the pyramid (Fig. 72). They were quarried away as building material by the Moslem builders of Cairo, especially from the fourteenth century A.D. In such finished masonry Petrie found joints displaying a contact of one five-hundredth of an inch, and joints of this kind are sometimes ten or twelve feet long. As Petrie has well said, we find here an accuracy like that of the manufacturing optician applied on a scale of acres.

The sovereign control of refractory materials by these consummate craftsmen at the beginning of the Pyramid Age is well illustrated by the new means of drilling which they had devised and the skill with which they applied it. The crank-drill of the Early Dynasties (Fig. 56) with a cutting edge of stone, which

Fig. 72. Blocks of Casing Masonry of the Lowest Course still in position on the North Side of the Great Pyramid. (Photograph by L. Dow Covington.)

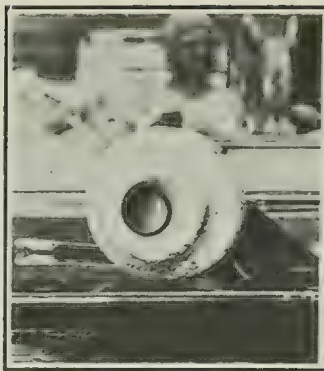
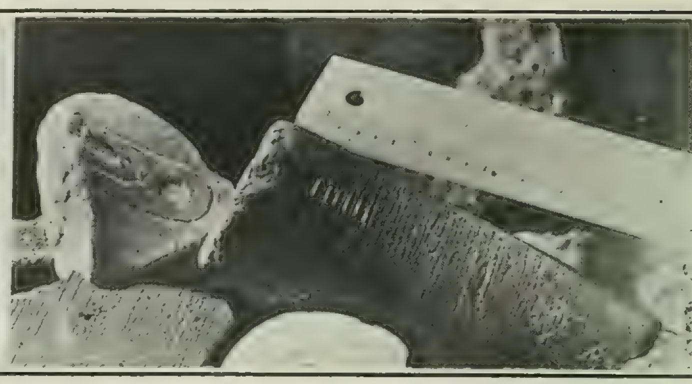



FIG. 73. UNFINISHED GRANITE VASE WITH THE BOTTOM OF THE CORE LEFT BY THE TUBULAR DRILL VISIBLE AT THE BASE OF THE BORE. (In the Field Museum of Natural History, Chicago.)
FIG. 74. CORE BROKEN OUT OF A HOLE MADE BY A TUBULAR DRILL AS SHOWN IN THE PRECEDING FIGURE. (From a photograph by Petrie.)

involved cutting out the entire mass of material included within its cylindrical bore, had been superseded by a tubular drill, presumably of copper reinforced by some cutting powder. It economized labor by boring around an interior core, which could later be broken away with a single blow (Figs. 73 and 74). This hollow tubular drill is a device which has been reinvented in our own time. The highly developed industries growing out of this ingenuity and skill in craftsmanship are elaborately displayed in colored relief sculptures in the masonry tombs of the nobles of the period at Gizeh (Fig. 67) and elsewhere in the great cemeteries of the Pyramid Age. Perhaps nothing better exemplifies the attainments which made Egypt the mother of arts than the sumptuous work of the lapidary and goldsmith (Fig. 75), which was already on its way to reach a supreme level of attainment never surpassed and rarely equaled in modern times.

The pyramid cemeteries likewise reveal to us the remarkable progress of this earliest highly cultivated age in architecture. In the development of fundamental architectural

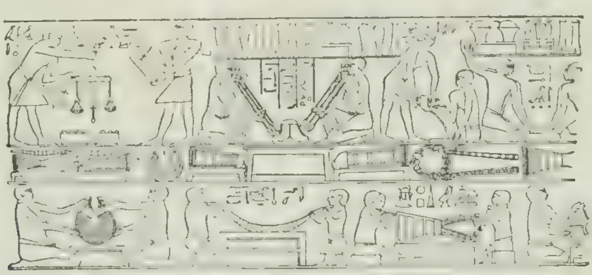


FIG. 75. GOLDSMITH'S WORKSHOP IN THE PYRAMID AGE. *Upper row:* At left chief goldsmith weighs out costly stones and a scribe records the weights; next six men with blow-pipes are blowing a fire in a small clay furnace; next a workman pours out paste; at right end four men are beating gold leaf. *Middle row:* Pieces of finished jewelry. *Lower row:* Workmen seated at low benches are putting together and engraving pieces of jewelry. Several of these men are dwarfs.

forms the so-called Second Pyramid of Gizeh (Fig. 76), built by Khafre (Greek *Chefren*, Fig. 77), displays some remarkable advances, especially in the buildings connected with it. The unprecedented exaltation of the Pharaoh's power and station was converting his tomb into a great architectural complex where the ancient and originally simple practices for the maintenance of the dead were carried on with a sumptuous magnificence which required a fitting architectural setting. The food, drink and clothing once regularly presented to the dead by merely

FIG. 76. SECOND PYRAMID OF GIZEH, BUILT BY KING KHAFRE IN THE 29TH CENTURY B.C. A bonnet of casing masonry is still preserved at the summit; below on the left we discern the ruins of the pyramid-temple described in the text and shown in Fig. 79. (By Underwood & Underwood, Copyright.)

setting it down before the simple tomb, now required a large and splendid building erected on the east side of the pyramid facing the royal city in the valley below. This building had thus become a mortuary temple, which we call a pyramid temple. Here ministered an endowed priesthood whose sole duty it was to maintain the offerings for the royal dead in the temple. They lived in the royal city below, and a long gallery, built of stone masonry a quarter of a mile in length, furnished them a convenient corridor, by means of which they could reach the temple above (Fig. 78). Giving access to this long cor-

FIG. 77. DIORITE PORTRAIT OF KING KHAFRE, BUILDER OF THE SECOND PYRAMID OF GIZEH (29TH CENTURY B.C.)

ridor there was at the lower or townward end, a monumental portal building, which seems to have served also as an additional and more conveniently accessible mortuary temple. It has therefore been appropriately termed by Reisner the "valley temple." All these parts making up the new and extensive pyramid complex may be easily recognized in Fig. 78.

In the development and design of these accessory structures the pyramid builders were confronted by fundamental problems of monumental architecture, in the solution of which they made great advances. Chief among these problems was that of carrying the roof over the void, and likewise the lighting of a hall with very thick side walls. To carry the roof over the void the Gizeh architects introduced into the hall a series of massive rectangular piers, each pier a monolithic block of polished granite (Fig. 80), brought from the First Cataract. The problem of lighting such a hall was met by raising higher than the roof on either side a middle section of the roof symmetrically placed along the axis of the building. The difference in level between this higher central portion of the roof and the lower portions on each side was occupied by light chutes, which furnished light to the hall through the roof (Fig. 79). The pyramid architects had thus produced an incipient nave roofed by a clerestory, with openings for light which were the ancestors of clerestory windows, and the fundamental elements of the basilica and its child the Christian basilica cathedral were therefore devised by the early Egyptian builders of the twenty-ninth century B.C.

Within three generations and not much more than a century after the erection of Khafre's splendid hall at Gizeh, the royal architects of Egypt were looking back upon the Gizeh buildings as crude and archaic. At Abusir, a few miles up the margin of the desert south of Gizeh, they were erecting for the Pharaohs of the Fifth Dynasty (2750 to 2625 B.C.) a wonderful

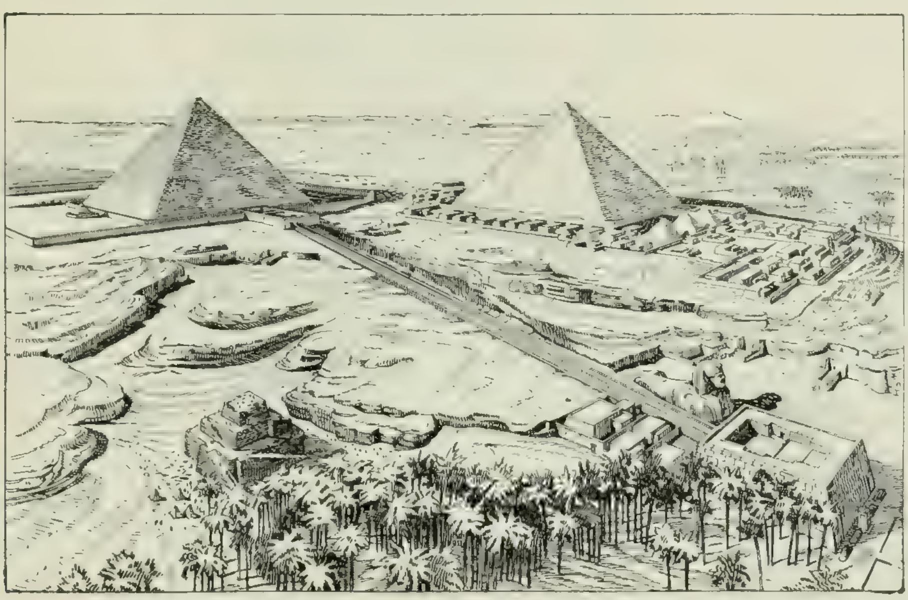


FIG. 78. RESTORATION OF THE GIZEH CEMETERY. (After Hoelscher.) The Great Pyramid of Khufu (Cheops) is on the right, from the summit of which the view in Fig 76 was taken; and the Second Pyramid of Khafre is on the left, with its temple and causeway or covered corridor connecting the temple above with the royal city below. Beside the "valley temple" giving access to the corridor is the Great Sphinx, a portrait of Khafre.

FIG. 79. INCIPIENT CLERESTORY IN THE HALL OF THE VALLEY TEMPLE OF KHAFRE AT GIZEH BUILT IN THE 29TH CENTURY B.C. The narrow light-chutes occupying the difference in level between a higher roof over the nave and a lower roof beside it are the lineal ancestors of the clerestory windows of European architecture. The oblique light which they admit is seen in Fig. 80.

series of tombs (Fig. 81) displaying remarkable progress in architecture. The Abusir pyramids themselves were to be sure much smaller and less imposing than those of Gizeh, but the pyramid temples at Abusir gave the Fifth Dynasty architects opportunities not presented by the pyramid form which was a matter already settled. In place of the bare rectangular Gizeh piers of a century earlier the Abusir architects designed a series of supports (Fig. 82) each representing a conventionalized palm tree, the trunk of which formed the shaft of a column, the capital being the graceful crown of foliage surmounting the whole. Thus emerged at the hands of Egyptian architects in the middle of the twenty-eighth century B.C. the earliest known columns and the first colonnades (Fig. 83).

These earliest colonnades are notable not only as such, but also because they are the earliest outstanding examples of the Egyptian use of decorative motives taken from the vegetable world. It showed the way for the development of the rich fund of decorative beauty which the architects and artists of western Asia and Europe, following Egypt, afterward discovered in vegetable forms, as they brought forth such things as the Corinthian column or the sumptuous carving of the Gothic cathedrals. Moving along the same line the Abusir architects also devised charming columns by the use of the lotus and papyrus, of which the latter became very common.

It is impossible within the limits of this brief sketch to discuss the social and governmental development which went on parallel with the amazingly rapid mechanical, industrial, artistic and architectural advance at which we have been glancing.

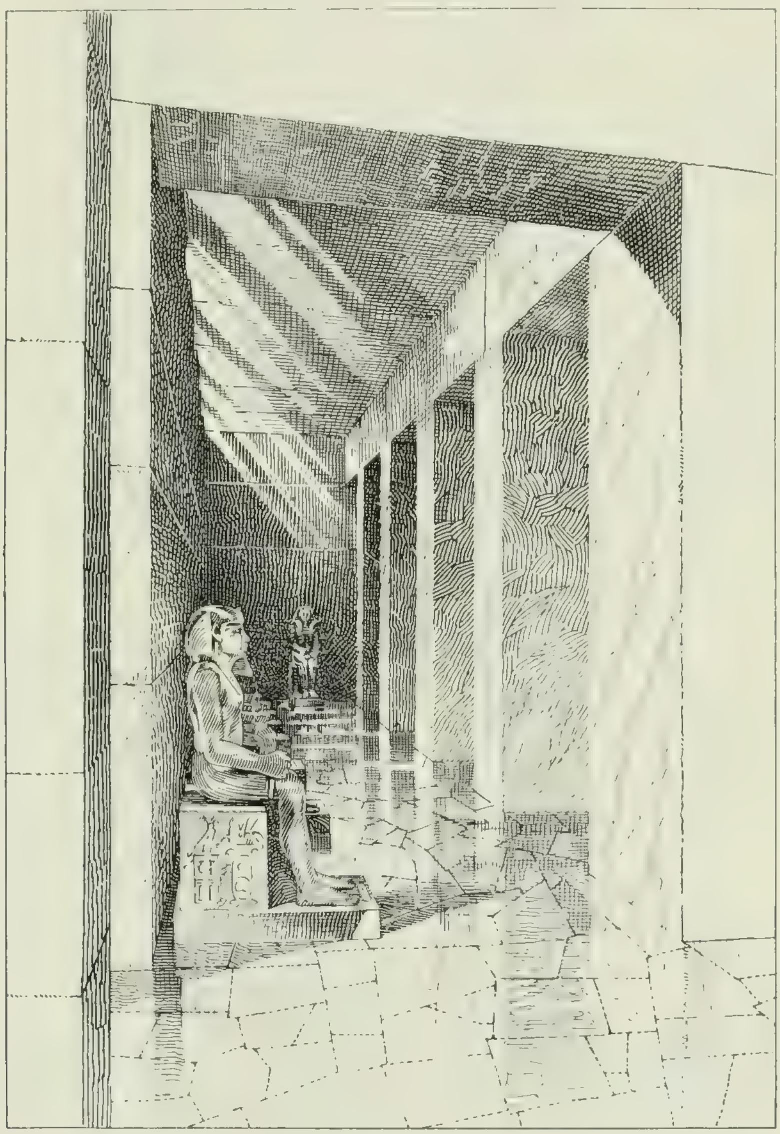


FIG. 80. RESTORATION OF CLERESTORY HALL IN THE VALLEY TEMPLE OF KHAFRE AT GIZEH. (After Hoelscher.) This is the hall seen beside the Great Sphinx at the foot of the long corridor in Fig. 78. A double row of the rectangular piers seen here supports a roof higher than that on either side of it and thus forms a real nave. The oblique light comes through the light-chutes, or incipient clerestory windows, as shown in Fig. 79.

FIG. 81. RESTORATION OF THE PYRAMID CEMETERY OF THE FIFTH DYNASTY AT ABUSIR BUILT IN THE 28TH AND 27TH CENTURIES B.C. (After Borchardt.) The pyramid of Sahure, built not long after 2750 B.C., with its corridor and temples is seen in the background. Here were found the colonades and the sea-going ships shown in Figs. 82–84.

As we recall the Nile valley of the Pleistocene Age, we are conscious of the marvelous transition through which it has passed. We of America are especially fitted to visualize and to understand the wonderful transformation of a wilderness into a land of splendid cities. But the men whose powers of achievement planted great and prosperous cities along the once lonely trails of our own broad land, received art, architecture, industry, commerce and social and governmental traditions as an inheritance from earlier times. There was an age, however, when the development from barbarism to civilization with all its impressive outward manifestations in art and architecture had to be accomplished *for the first time.* That happened along the Nile, and it seems therefore like a magical transition, as we see the trail of the Stone Age hunter leading up from the river through the jungle marsh, transformed into an avenue of sculptured sphinxes and tall obelisks; while in the background where once the trail terminated at the hunter's group of wattle huts peeping through the reeds, there rises a stately city adorned with imposing temples and monuments of stone.

The prehistoric hunter whose self-expression was quite content to ply the flint graving tool in carving symmetrical lines of game beasts along the ivory handle of a flint dagger has been transformed by fifty generations of social evolution into a royal architect, able to transmute his visions of a great state into architectural forms of dignity and splendor, launching great bodies of organized craftsmen upon the quarries of the Nile cliffs, and summoning thence stately and rhythmic colonnades, imposing temples and a vast rampart of pyramids, the greatest tombs ever erected by the hand of man. We must regard these things, therefore, as the outward and monumental expression of man's social and governmental advance, with which we must also remember his unfolding inner life had kept even pace. The quickened imagination which finds expression in noble architectural forms is to a large extent a product of social development, of an imposing vision of the kingship and of the state, as well as of the exalted station of the gods who guide the state. These were new forces unknown to the life of the primitive hunters who elsewhere outside of the Egypto-Babylonian group, still continued to live by the chase throughout most of the world, or had here and there, within reach of influences from the Egypto-Babylonian group, made a beginning in agriculture and cattle-breeding.

In view of the tiny city-kingdoms, disunited and fighting among themselves, which at this time were the only organized

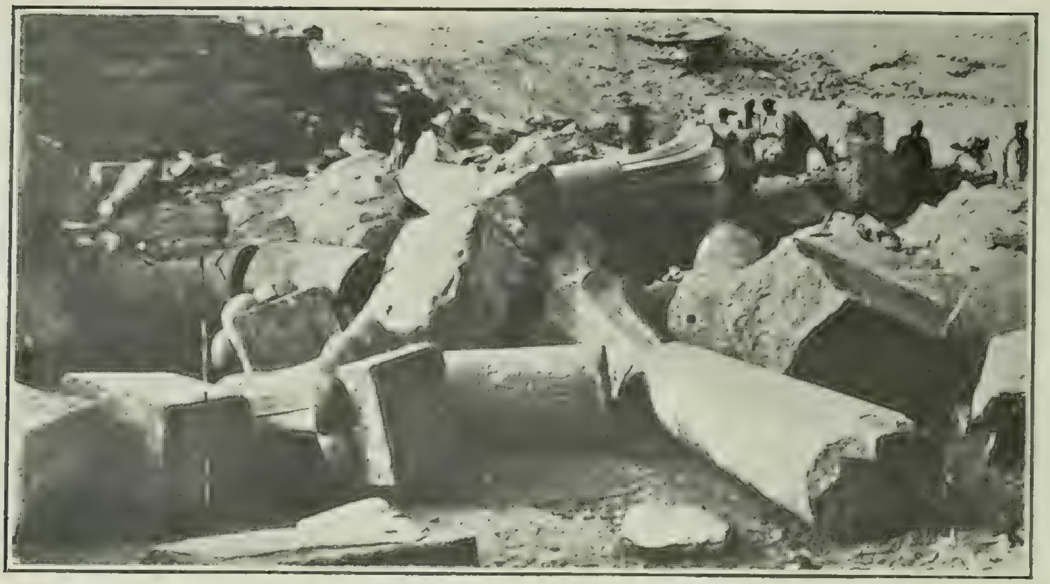


FIG. 82. MONOLITHIC GRANITE COLUMNS AS FOUND BY BORCHARDT IN THE TEMPLE OF SAHURE AT ABUSIR. (Compare Fig. 81.)

states in Babylonia, it is evident that the first great civilized nation of highly cultivated life had come into being on the Nile. Such a fabric of civilized life developed by a great community of several million souls could not exist for five hundred years without exerting a profound influence in the adjacent Mediterranean upon which it looked out and likewise in neighboring Asia which began at the eastern delta gates. The evidences for early Egyptian influences moving across the Mediterranean

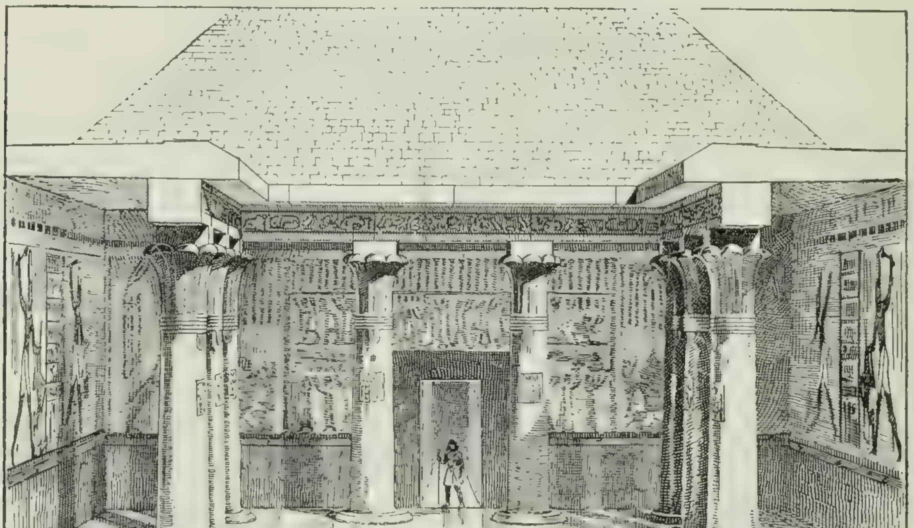


FIG. 83. RESTORATION OF THE COLONNADED COURT OF THE PYRAMID TEMPLE OF SAHURE. (After Borchardt.) From the columns found as shown in Fig. 82 it was not difficult to restore the court as it was left by the architects. This court is the oldest colonnaded structure now known in the history of architecture, having been erected not long after the middle of the 28th century B.C. It is evidently the ancestor of the colonnaded courts of Hellenistic Europe as shown in Fig. 123.

FIG. 84. EARLIEST REPRESENTATION OF A SEA-GOING SHIP, FOUND AMONG THE WALL RELIEFS IN THE PYRAMID TEMPLE OF SAHURE. (After Borchardt.) The Pharaohs of the Third Dynasty in the 30th century B.C. were already carrying on commerce in the Mediterranean with such ships as this, although this relief scene was sculptured in the middle of the 28th century. Such vessels represent the beginning of salt sea navigation.

and entering Stone Age Europe are now obvious enough. From a study of the archaic remains of Crete Sir Arthur Evans observes: "The possibility of some actual immigration into the island of the older Egyptian element . . . can not be excluded."[27] The excavation of the Abusir pyramids and temples has revealed the ships which carried these Egyptian influences across the eastern Mediterranean (Fig. 84). These are the earliest known sailing ships and the earliest sea-going craft of which we know the form and rig. When the Mediterranean peoples, like the Phœnicians, afterward likewise took to the sea, their ships (Fig. 116) were reproductions of these Egyptian vessels. It is therefore evident that the Egyptian sailing ships which crossed the Mediterranean at the beginning of the Pyramid Age as early as the thirtieth century B.C. were not only the first sea-going ships devised by man, but were likewise the ancestors of all salt-water craft of the early world, and hence of the modern world also. The native shipping of East Indian waters to this day exhibits details and characteristics which are of unmistakable ancient Egyptian origin.

(To be continued.)

[27] "New Archæological Lights on the Origins of Civilization in Europe," presidential address before the British Association, 1916, reprinted Annual Rep. Smithsonian Inst., 1917, p. 441.

THE PROGRESS OF SCIENCE

THE ST. LOUIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE American Association for the Advancement of Science will hold its seventy-second stated meeting at St. Louis during the week beginning on Monday, December 29. It will be the eighteenth of the convocation-week meetings of the national scientific societies. Meetings of the council, and all sessions of the association and of the affiliated societies will be held in the Soldan High School. Hotel Statler will be the general headquarters. The local executive committee consists of George T. Moore, Alexander S. Langsdorf, Augustus G. Pohlman, John W. Withers and John M. Wulfing.

The opening general session of the association will be held on Monday night, in the Assembly Room of the Soldan High School. Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, will preside. General announcements concerning the meeting will be made, the revised constitution of the associaion will be presented for vote and the retiring president, Professor John Merle Coulter, of the University of Chicago, will deliver his address on "The Evolution of Botanical Research." The meeting will be followed by an informal reception to members of the American Association and of affiliated societies.

THE SOLDEN HIGH SCHOOL.
Headquarters for the St. Louis Meeting of the American Association for the Advancement of Science.

MAIN ENTRANCE OF THE MISSOURI BOTANICAL GARDEN FROM THE INTERIOR.

The addresses of the retiring vice-presidents of the sections, to be delivered throughout the week are as follows:

Section A.—George D. Birkhoff. "Recent advances in dynamics."
Section B.—Gordon F. Hull. "Some aspects of physics in war and peace."
Section C.—Alexander Smith. "Chemistry as it is taught."
Section D.—Ira N. Hollis. "Industrial problems of the United States."
Section E.—David White. "Geology as taught in the United States."
Section F.—William Patten. "The message of the biologist."
Section G.—Albert F. Blakeslee. "Sexuality in the mucors."
Section H.—Aleš Hrdlička. "The relations of psychology and anthropology."
Section I.—John Barrett. "New after-the-war phases of practical Pan-Americanism."
Section K.—F. S. Lee. "The untilled fields of public health."
Section L.—Stuart A. Courtis. "The part played by heredity and maturity as factors conditioning the effects of training."
Section M.—Henry P. Armsby. "The organization of research."

On Tuesday night, December 30, Dr. Simon Flexner, president of the association, will deliver a popular lecture, complimentary to the members of the association and affiliated societies and to the general public.

The American Association has met twice before in St. Louis, in 1878 and 1903, the latter being the second of the convocation-week meetings following the inauguration of the plan the year before at Washington. During the forty-one years that have elapsed since the first St. Louis meeting, there has been a westward movement of scientific institutions and scientific men, so that the center of our scientific population is tending to approach the general center of population which is now in Indiana, but which is moving in the direction of St. Louis.

The educational and scientific institutions of the city—exceeded in size only by New York, Philadelphia and Chicago—are commensurate with its commercial position. Washington University with its

Main Conservatories of the Missouri Botanical Garden looking across the Rose Garden.

great medical school has long been one of the strongest non-state-supported institutions west of the Atlantic seaboard, and has guarantees for future development. St. Louis University is a leading Catholic institution. The public-school system has maintained the position given to it on the days when William T. Harris was superintendent. An Academy of Science was organized in 1856. The Missouri Botanical Garden, established by Henry Shaw, is one of our chief centers for research in botany. The St. Louis Exposition of 1904 and its International Congress of Arts and Sciences gave the city a historical position in scientific cooperation among the nations.

NATIONAL SCIENTIFIC SOCIETIES MEETING AT ST. LOUIS

The American Association has established a general convocation-week meetings once in four years, held successively in Washington, Chicago and New York. One of these meetings will occur next year in Chicago, and it is hoped that at that time all the national scientific societies will join together in a meeting that will give impressive evidence of the members and influence of scientific men. In the intervening years many of the scientific societies prefer to hold separate meetings. Thus this year the geologists, psychologists and anthropologists meet in Boston, the American Society of Naturalists at Princeton, the Federation of Biological Societies, which had planned to meet in Toronto has been compelled unexpectedly to change to Cincinnati, the American Association of University Professors will meet with the political science and historical associations in Cleveland. The list of national scientific societies meeting at St. Louis is so long that we can only record their names and their officers, which are as follows:

Mathematical Association of America.—(Missouri Section.) December 29. President, H. E. Slaught; Secretary, Professor Paul R. Rider, Washington University, St. Louis, Mo.

American Mathematical Society.—(Chicago and Southwestern Sections.) December 30 and 31. Joint session with Section A on December 30. Acting Secretary, Dr. Arnold Dresden, 2114 Vilas St., Madison, Wis.

American Federation of Teachers of the Mathematical and the Natural Sciences.—Secretary, Dr. William A. Hedrick, Central High School, Washington, D. C.

American Meteorological Society.—December 29 to 31; joint meetings with Sections B and E on dates to be announced. Secretary, Dr. Charles F. Brooks, U. S. Weather Bureau, Washington, D. C.

American Physical Society.—December 30 to January 1, in joint session with Section B, President, J. S. Ames. Secretary, Dr. Dayton C. Miller, Case School of Applied Science, Cleveland, Ohio.

Society for the Promotion of Engineering Education.—President, Arthur M. Greene, Jr. Secretary, Professor Frederic L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

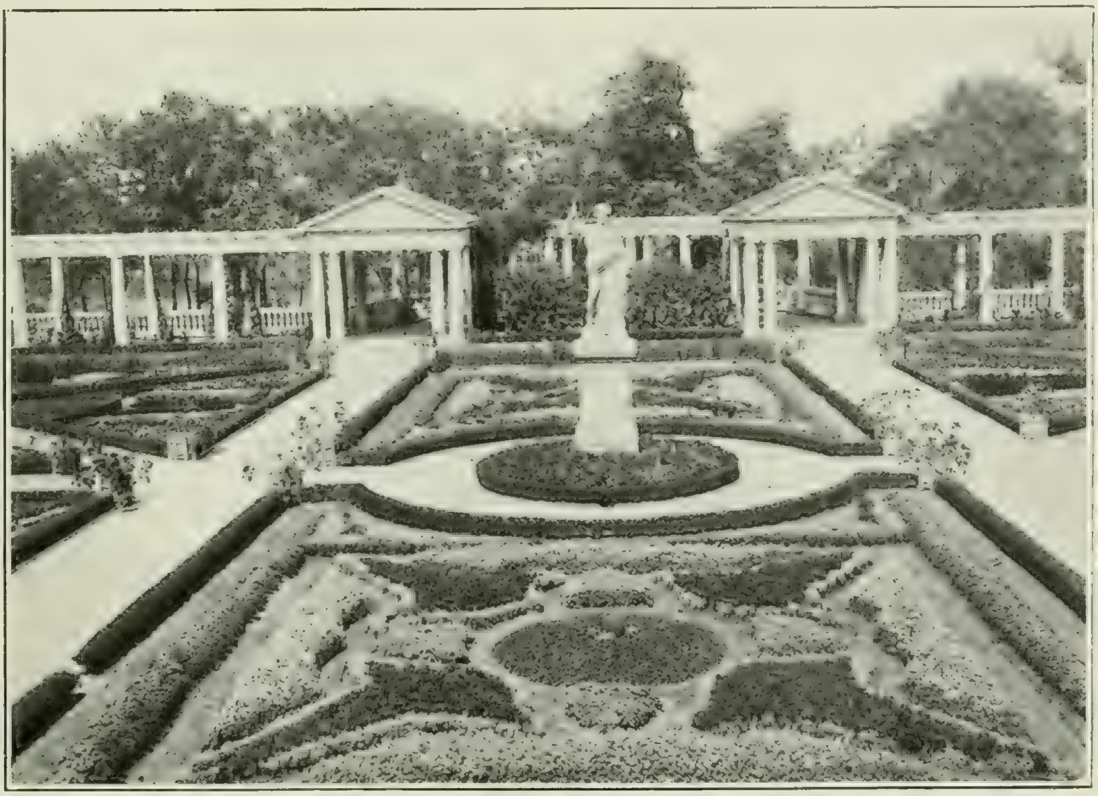
Optical Society of America.—January 2. President, F. E. Wright. Secretary, Dr. P. G. Nutting, Westinghouse Research Laboratory, East Pittsburgh, Pa.

Association of American Geographers.—December 30 to January 1. President and Acting Secretary, Dr. Charles R. Dryer, Oak Knoll, Fort Wayne, Ind.

National Council of Geography Teachers.—December 29 and 30. President, Albert P. Brigham. Secretary, Professor George J. Miller, State Normal School, Mankato, Minn.

American Society of Zoologists.—December 29 to 31, in joint session with Section F. Joint session with Ecological Society of America on Tuesday afternoon, December 30. Zoologists' dinner, with address of Vice-president of Section F and moving picture films of Barbadoes-Antigua Expedition by C. C. Nutting, on Wednesday night, December 31. President, C. M. Child. Secretary, Dr. W. C. Allee, Lake Forest College, Lake Forest, Ill.

Entomological Society of Amer-



Central Panel of the Italian Garden.

ica.—December 29 and 30. President, J. G. Needham. Secretary, Dr. J. M. Aldrich, U. S. National Museum, Washington, D. C.

American Association of Economic Entomologists. — December 31 to January 2. President, W. C. O'Kane. Secretary, Albert F. Burgess, Gipsy Moth Parasite Laboratory, Melrose Highlands, Mass.

Botanical Society of America.—December 30 to January 1, with joint sessions as follows: Tuesday, December 30, Section G; Wednesday, December 31, American Society for Horticultural Science; Thursday, January 1, 10 A.M., Ecological Society of America, 2 P.M., American Phytopathological Society. On Wednesday night, December 31, will be the annual dinner for all botanists, followed by presidential address. President, J. C. Arthur. Secretary, Professor J. R. Schramm, N. Y. State College of Agriculture, Ithaca, N. Y.

American Phytopathological Society.—President, C. L. Shear. Secretary, Dr. G. R. Lyman, U. S. Department of Agriculture, Washington, D. C.

American Society for Horticultural Science.—December 29 to 31. President, J. W. Crow. Secretary, Professor C. P. Close, College Park, Md.

Association of Official Seed Analysts.—Will meet on Monday and Tuesday, December 29 and 30. President, H. D. Hughes. Secretary, R. C. Dahlberg, University Farm, St. Paul, Minn.

Ecological Society of America.—December 30 to January 1, with joint session with the American Society of Zoologists on Tuesday, December 30, and with Botanical Society of America on Thursday, January 1. President, Barrington Moore. Secretary, Dr. Forrest Shreve, Desert Botanical Laboratory, Tuscon, Arizona.

American Pomological Society.—December 30 to January 1. President, L. H. Bailey. Secretary, Professor Edward R. Lake, Hotel St. Nicholas, Albany, Ga.

American Microscopical Society.—December 30, for luncheon and executive committee and on Wednesday, December 31, for business meeting just following Section F afternoon session. President, L. E. Griffin. Secretary, Professor Paul S. Welch, University of Michigan, Ann Arbor, Mich.

American Nature-Study Society.—December 30. President, L. H. Bailey. Secretary, Dr. Anna Botsford Comstock, Cornell University, Ithaca, N. Y.

Wilson Ornithological Club.—December 29 and 30. President, Myron H. Swenk. Secretary, Professor Albert F. Gainer, 924 Broadway, Nashville, Tenn.

American Metric Association.—December 29 and 30. President, George F. Kunz. Secretary, Howard Richards, Jr., 156 5th Avenue, New York, N. Y.

Society for the Promotion of Agricultural Science. — Secretary, Dr. C. P. Gillette, Colorado Agricultural College, Fort Collins, Colo.

Society of Sigma Xi.—President, Julius Stieglitz. Secretary, Dr. Henry Baldwin Ward, University of Illinois, Urbana, Ill.

Gamma Alpha Graduate Scientific Fraternity.—President, Norman E. Gilbert. Secretary, Dr. Albert H. Wright, Cornell University, Ithaca, N. Y.

Phi Kappa Phi.—December 31. President, Edwin E. Sparks. Secretary, Dr. L. H. Pammel, Iowa State College, Ames, Iowa.

Gamma Sigma Delta.—Thursday, January 1. President, C. H. Eckles. Secretary, Dr. L. H. Pammel, Iowa State College, Ames, Iowa.

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

ANNOUNCEMENT is made that Mr. John D. Rockefeller has added $10,000,000 to his previous endowment of the Rockefeller Institute for Medical Research. This gift, the largest made by Mr. Rockefeller at one time to the institution, is to meet rapidly growing needs in its many lines of research and in making new knowledge available in the protection of the public health and in the improved treatment of disease and injury.

By this increase in the endowment, new lines of research will be sustained in biology, chemistry and physics, upon which medical science so largely rests, as well as in medicine itself, as will the study of many practical problems directly relating to diseases in men and animals which are already under way.

The local activities of the Rockefeller Institute in New York are chiefly carried on in the great laboratories and the hospital, which stand high on the bluff facing the East River, between East 64th and 67th Streets, a part of the old Schermerhorn Farm of an earlier day.

Near Princeton, N. J., the institute has a large farm, where it maintains a department of animal pathology. The laboratories and various accessory buildings here are devoted to research on the diseases of animals and effective methods for their prevention and cure, as well as to the study of the bearing of animal diseases upon the health and economic interests of man.

The scientific staff of the Rockefeller Institute numbers sixty-five, most of them highly trained and of large experience in the subjects to which they are exclusively devoted. The institute further employs 310 persons in its technical and general service. It is to the perpetual maintenance of such a group of men and women, with adequate facilities and suitable conditions for their successful work, for the general welfare, that the gifts of Mr. Rockefeller to the institute are devoted.

The scientific staff consists of members, associate members, associates and assistants. The members are:

Simon Flexner, pathology and bacteriology; director of the Laboratories.
Rufus Cole, medicine; director of the Hospital; physician to the Hospital.
Theobald Smith, director of the department of animal pathology.
Alexis Carrel, experimental surgery.
P. A. Levene, chemistry.
Jacques Loeb, experimental biology.
S. J. Meltzer, physiology and pharmacology.
Hideyo Noguchi, pathology and bacteriology.

PROBLEMS OF FOOD AND NUTRITION

THE National Research Council has formed a special committee on Food and Nutrition Problems, composed of a group of the most eminent physiological chemists and nutrition experts of the country. The members are: Carl Alsberg, chief, bureau of chemistry, Department of Agriculture; H. P. Armsby, director of the institute of animal nutrition, Pennsylvania State College; Isabel Bevier, director of department of home economics, University of Illinois; E. B. Forbes, chief, department of nutrition, Ohio Agricultural Experiment Station; W. H. Jordan, director, N. Y. Agricultural Experiment Station; Graham Lusk, professor of physiology, Cornell University Medical College; C. F. Langworthy, chief of office of home economics, Department of Agriculture; E. V. McCollum, professor of biochemistry, School of Public Health and Hygiene, Johns Hopkins University; L. B. Mendel, professor of physiological chemistry, Yale University; J. R. Murlin, professor of physiology and director of the department of vital economics, University of Rochester; R. A. Pearson, president of the Iowa State Agricultural College; H. C. Sherman, professor of food chemistry, Columbia University; A. E. Taylor, Rush professor of physiological chemistry, University of Pennsylvania; and A. F. Woods, botanist, president of Maryland State College of Agriculture.

This committee will devote its attention and activities to the solution of important problems connected with the nutritional values and most effective grouping and preparation of foods, both for human and animal use. Special attention will be given to national food conditions and to comprehensive problems involving the coordinated services of numerous investigators and laboratories. The committee, with the support of the council, is arranging to obtain funds for the support of its researches, and will get under way, just as soon as possible, certain specific investigations already formulated by individual committee members and subcommittees. These include studies of the comparative food values of meat and milk and of the conditions of production of these foods in the United States, together with the whole problem of animal nutrition; the food conditions in hospitals, asylums and similar institutions; the nutritional standards of infancy and adolescence; the formation of a national institute of nutrition; and other problems of similarly large and nationally important character.

SCIENTIFIC ITEMS

WE record with regret the death of Louis Valentine Pirsson, professor of geology in the Yale University, and of Allan McLane Hamilton, at one time professor of mental diseases in the Cornell Medical College.

THE Nobel prize for physics for 1918 has been awarded to Professor Max Planck, of Berlin, and for 1919 to Professor Stark, of Greifswald. The prize for chemistry for 1918 has been awarded to Professor Fritz Haber, of Berlin.—The National Academy of Sciences has awarded its medal for eminence in the application of science to the public welfare to Mr. Herbert C. Hoover for his applications of science in the conservation, selection and distribution of food.

DR. DAVID P. BARROWS, professor of education and later of political science in the University of California, at one time director of education for the Philippine Islands and author of works on the islands, has been elected president of the University of California, to succeed Dr. Benjamin Ide Wheeler.—Dr. Frank Schlesinger, director of the Allegheny Observatory of the University of Pittsburgh, has been elected director of the Yale Observatory.—Dr. Richard M. Pearce, professor of research medicine in the University of Pennsylvania under the John Herr Musser Foundation, has accepted the position of director of the newly established division of medical education of the Rockefeller Foundation. Dr. Pearce has sailed for Europe to carry out work in the interest of the foundation.

WITH the exception of approximately $25,000,000 the will of Henry C. Frick leaves his estate, believed to be worth approximately $145,000,000, for public, charitable and educational purposes. Mr. Frick's house and art collection in New York City, which after the termination of Mrs. Frick's life estate are to go the public, are valued at approximately $50,000,000. An endowment of $15,000,000 is provided to maintain this as " The Frick Collection." Pittsburgh, where much of Mr. Frick's wealth was acquired, receives a tract of about 151 acres of land in the 14th ward of that city for a park and $2,000,000 in trust to maintain and improve the property. The residuary estate to be divided into 100 shares valued at about $500,000 each, is left in nineteen institutions. Princeton University receives thirty of these shares, Harvard University, The Massachusetts Institute of Technology, and the Educational Fund Commission Pittsburgh, each receives ten shares.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1920

THE TERMITODOXA, OR BIOLOGY AND SOCIETY[1]

By Professor WILLIAM MORTON WHEELER

BUSSEY INSTITUTION, HARVARD UNIVERSITY

JUST before the World War we seemed to be on the verge of startling revelations in animal behavior. "Rolf," the Ayrdale terrier of Mannheim, was writing affectionate letters to Professor William Mackenzie of Genoa, and the Elberfeld stallions were easily solving such problems in mental arithmetic as extracting the cube root of 12,167, to the discomfiture of certain German professors, who had never been able to detect similar signs of intelligence in their students. The possibilities of animal correspondence struck me as so promising that I longed to dispatch letters and questionnaires to all the unusual insects of my acquaintance. But dismayed at the thought of the quantity of mail that might reach me, especially from the many insects that have been misrepresented by the taxonomists or maltreated by the economic entomologists, I decided to proceed with caution and to confine myself at first to a single letter to the most wonderful of all insects, the queen of the West African *Termes bellicosus*. During the autumn of 1915 my friend, Mr. George Schwab, missionary to the Kamerun, kindly undertook to deliver my communication to a populous termitarium of this species in his back yard in the village of Okani Olinga. He subsequently wrote me that my constant occupation with the ants must have blinded me to the fact that the termitarium, unlike the formicarium, contains a king as well as a queen, but that the *bellicosus* king was so accustomed to being overlooked, even by his own offspring, that he not only pardoned my discourtesy but condescended to

[1] Read at the Symposium of The American Society of Naturalists, Princeton Meeting, Dec. 30th, 1919.

answer my letter. Mr. Schwab embarked for Boston in 1917. Off the coast of Sierra Leone his steamer was shelled by a German submarine camouflaged as a small boat in distress, but succeeded in escaping and what would have been another atrocity, the loss of the king's letter, was averted. It runs as follows:

Dear Sir: Your communication addressed to my most gloriously physogastric consort, was duly received. Her majesty, being extremely busy with oviposition—she has laid an egg every three minutes for the past four years—and fearing that an interruption of even twenty minutes might seriously upset the exquisitely balanced routine of the termitarium, has requested me to acknowledge your expression of anxiety concerning the condition of the society in which you are living and to answer your query as to how we termites, to quote your own words, "managed to organize a society which, if we accept Professor Barrell's recent estimates of geological time, based on the decomposition of radium, has not only existed but flourished for a period of at least a hundred million years."

I answer your question the more gladly, because the history of our society has long been with me a favorite topic of study. As you know, the conditions under which I live are most conducive to sustained research. I am carefully fed, have all the leisure in the world and the royal chamber is not only kept absolutely dark and at a constant and agreeable temperature even during the hottest days of the Ethiopian summer, but free from all noises except the gentle rhythmic dropping of her majesty's eggs and the soft footfalls of the workers on the cement floor as they carry away the germs of future populations to the royal nurseries. And you will not wonder at my knowledge of some of the peculiarities of your society when I tell you that in my youth I belonged to a colony that devoured and digested a well-selected library belonging to a learned missionary after he had himself succumbed to the appetite of one of the fiercest tribes of the Kamerun. If I extol the splendid solutions of sociological problems by my remote ancestors, I refrain from suggesting that your society would do well to imitate them too closely. This, indeed, would be impossible. I believe, nevertheless, that you may be interested in my remarks, for, though larger and more versatile, you and your fellow human beings are after all only animals like myself.

According to tradition our ancestors were descended in early Cretaceous times from certain kind-hearted old cockroaches that lived in logs and fed on rotten wood and mud.

Their progeny, the aboriginal termites, although at first confined to this apparently unpromising diet, made two important discoveries. First, they chanced to pick up a miscellaneous assortment of Protozoa and Bacteria and adopted them as an intestinal fauna and flora, because they were able to render the rotten wood and mud more easily digestible. The second discovery, more important but quite as incidental, was nothing less than society. Our ancestors, like other solitary insects, originally set their offspring adrift to shift for themselves as soon as they hatched, but it was found that the fatty dermal secretions, or exudates of the young, were a delicious food and that the parents could reciprocate with similar exudates as well as with regurgitated, predigested cellulose. Thenceforth parents and offspring no longer lived apart, for an elaborate exchange of exudates, veritable social hormones, was developed, which, continually circulating through the community, bound all its individuals together in one blissful, indissoluble, syntrophic whole, satisfied to make the comminution and digestion of wood and mud the serious occupation of existence, but the swapping of exudates the delight of every leisure moment. It may be said, therefore, that our society did not arise, like yours, from a combination of selfish predatism and parasitism but from a coöperative mutualism, or symbiosis. In other words, our ancestors did not start society because they thought they loved one another, but they loved one another because they were so sweet, and society supervened as a necessary and unforeseen by-product.

You will admit that no society could have embarked on its career through the ages with more brilliant prospects. The world was full of rotten wood and mud and no laws interfered with distilling and imbibing the social hormones. But in the Midcretaceous our ancestors struck a snag. Not only had all the members of society begun to reproduce in the wildest and most unregulated manner, but their behavior toward one another had undergone a deterioration most shocking to behold. The priests, pedagogues, politicians and journalists having bored their way up to the highest strata of the society undertook to influence or control all the activities of its members. The priests tried to convince the people that if they would only give up indulging in the social hormones and confine themselves to a diet of pure mud, they would in a future life eat nothing but rose-wood and mahogany, and the pedagogues insisted that every young termite must thoroughly saturate himself with the culture and languages of the Upper Carboniferous cockroaches.

Some suspected that the main value of this form of education lay in intensifying and modulating the stridulatory powers, but for several thousand years most termites implicitly believed that ability to stridulate, both copiously and sonorously, was an infallible indication of brain-power. The politicians and the journalists—well, were it not that profanity has been considered to be very bad form in termite society since the Miocene, I might make a few comments on *their* activities. Suffice it to say that they consumed even more cellulose than the priests and pedagogues and secreted such a quantity of buncombe and flapdoodle that they well nigh asphyxiated the whole termitarium. Meanwhile in the very foundations of the commonwealth anarchists, syndicalists, I. W. W. and bolsheviki were busy boring holes and filling them with dynamite, while the remainder of society was largely composed of profiteers, grafters, shysters, drug-fiends and criminals of all sizes interspersed with beautifully graduated series of wowsers, morons, feeble-minded, idiots and insane. [At this point the king has introduced a rather trivial note on the word "wowser." This word, he says, was first employed by the termites of Australia but later adopted by the human inhabitants of that continent, to designate an individual who makes a business of taking the joy out of life, one who delights in pouring cold water into his own and especially into other peoples' soup. The term appears to be onomatopœic to judge from a remark by one of our postcretaceous philologists who asserts that "whenever the wowser saw termites dancing, swearing, flirting, smoking or over-indulging in the social hormones, he sat up on his hind legs, looked very solemn, swelled out his abdomen and said Wow!"]

To such depths, my dear sir, the letter continues, had termite society fallen in the Midcretaceous. The few sane termites still extant were on the point of giving up social life altogether and of returning to the solitary habits of the Palæodictyoptera, but a king, Wuf-wuf IV., of the 529th dynasty, succeeded in initiating those reforms which led our ancestors to complete the most highly integrated social organization on the planet. He has aroused the enthusiastic admiration and emulation of every sovereign down to the present time. I can best describe him by saying that in his serious moments he displayed the statesmanship of a Hammurabi, Moses, Solomon, Solon and Pericles rolled into one and that in his moments of relaxation he was a delightful blend of Aristophanes, Lucian, Rabelais, Anatole France and Bernard Shaw. This king had the happy thought to refer the problems of social reform to the biologists. They were unfortunately few in number and difficult to find, because each was sitting in his hole in some remote corner of the termitarium, boring away in blissful ignorance of the depravity of the society to which he belonged. In obedience to the king's request, however, they were finally rounded up and persuaded to meet together annually just after the winter solstice for the purpose of stridulating about the relations of biology to society. After doing this for ten million years they adopted a program as elegant as it was drastic for the regeneration of termite society, and during the remaining fifteen million years of the Cretaceous they succeeded in putting their plan into operation. I can give you only the baldest outline of this extraordinary achievement.

Our ancient biological reformers started with the assumption that a termite society could not be a success unless it was constructed on the plan of a superorganism, and that such a superorganism must necessarily conform to the fundamental laws of the individual organism. As in the case of the individual, its success would have to depend on the adequate solution of the three basic problems of nutrition, reproduction and protection. It was evident, moreover, that these problems could not be solved without a physiological division of labor among the individuals composing the society, and this, of course, implied the development of classes, or castes. Termite society was therefore divided into three distinct castes, according to the three fundamental organismal needs and functions, the workers being primarily nutritive, the soldiers defensive and the royal couple reproductive. Very fortunately our earliest social ancestors had not imitated our deadly enemies, the ants, who went crazy in the early Cretaceous on the subject of parthenogenesis and developed a militant suffragette type of society, but insisted on an equal representation of both sexes in all the social activities. Our society is therefore ambisexual throughout, so that, unlike the ants, we have male as well as female soldiers and workers. It was early decided that these two castes should be forbidden to grow wings or reproduce and that the royal caste should be relieved from all the labor of securing food and defending the termitarium in order to devote all its energies to reproduction. The carrying out of this scheme yielded at least two great advantages: first, the size of the population could be automatically regulated to correspond with the food-supply, and second, the production of perfect offspring was greatly facilitated.

During the late Cretaceous period of which I am writing our practical geneticists, in obedience to a general demand for a more varied diet, made two important contributions to our social life. The plant breeders found that what was left of the comminuted wood after its passage through the intestines of the worker termites could be built up in the form of elaborate sponge-like structures and utilized as gardens for the growth of mushrooms. Cultivation was later restricted to a few selected varieties of mushrooms which the biochemists had found to contain vitamins that accelerated the growth of the tissues in general and of the spermatocytes and oöcytes in particular. And for this reason only the royal caste and the young of the other castes were permitted to feed on this delicious vegetable food. The animal breeders of that age made a more spectacular though less useful contribution when they persuaded our ancestors to adopt a number of singular beetles and flies and to feed and care for them till they developed exudate organs. Owing to the stimulating quality of their exudates these creatures, the termitophiles, added much variety to the previously somewhat monotonous social hormones. This quality, however, made it necessary to restrict the number of termitophiles in the termitarium for the same reason that your society would find it advisable to restrict the cattle industry if your animal breeders had succeeded in producing breeds of cows that yielded highballs and cocktails instead of milk.

It is, of course, one thing to have a policy and quite another to carry it out. The anarchistic elements in our late Cretaceous society were so numerous and so active that great difficulty was at first experienced in putting the theories of the biological reformers into practise, but eventually, just before the Eocene Tertiary, a very effective method of dealing with any termite that attempted to depart from the standards of the most perfect social behavior was discovered and rigorously applied. The culprit was haled before the committee of biochemists who carefully weighed and examined him and stamped on his abdomen the number of his colloidal molecules. This number was taken to signify that his conduct had reduced his social usefulness to the amount of fat and proteids in his constitution. He was then led forth into the general assembly, dismembered and devoured by his fellows.

I describe these mores reluctantly and very briefly, because I fear that they may shock your sensibilities, but some mention of them is essential to an appreciation of certain developments in our society within recent millennia. So perfectly socialized have we now become that not infrequently a termite who has a slight indisposition, such as a sore throat or a headache or has developed some antisocial habit of thought or is merely growing old, will voluntarily resort to the committee of biochemists and beg them to stamp him. He then walks forth with a radiant countenance, stridulating a refrain which is strangely like George Eliot's "O, may I join the choir invisible!" and forthwith becomes the fat and proteid "Bausteine" of the crowd that assembles on hearing the first notes of his petition. If you regard this as an even more horrible exhibition of our mores, because it adds suicide to murder and cannibalism, I can only insist that you are viewing the matter from a purely human standpoint. To the perfectly socialized termite nothing can be more blissful or exalted than feeling the precious fats and proteids which he has amassed with so much labor, melting, without the slightest loss of their vital values, into the constitutions of his more vigorous and socially more efficient fellow beings.

Now I beg you to note how satisfactory was our solution of the many problems with which all animals that become social are confronted. I need hardly emphasize the matter of nutrition, for you would hardly contend that animals that can digest rotten wood and mud, grow perennial crops of mushrooms on their excrement, domesticate strange animals to serve as animated distilleries and digest not only one anothers' bodies but even one anothers' secretions, have anything to learn in dietetics or food conservation. Our solution of the great problems of reproduction, notably those of eugenics, is if anything, even more admirable, for by confining reproduction to a special caste, by feeding it and the young of the other castes on a peculiarly vitaminous diet and by promptly and deftly eliminating all abnormalities, we have been able to secure a physically and mentally perfect race. You will appreciate the force of this statement when I tell you that in a recent census of the 236,498 individuals comprising the entire population of my termitarium, I found none that had hatched with more than the normal number of antennal joints or even with a misplaced macrochæta. The only anomaly seen was one of no social significance, a slightly defective toenail in three workers. Rigid eugenics combined with rigid enforcement of the regulations requiring all antisocial, diseased and superannuated individuals promptly to join the choir invisible, at the same time solved the problems of ethics and hygiene, for we were thus enabled, so to speak, to ram virtue and health back into the germ-plasm where they belong. And since we thus compelled not only our workers and soldiers but even our kings and queens to be born virtuous and to continue so throughout life, the Midcretaceous wowser caste, finding nothing to do, automatically disappeared. The problem of social protection was solved by the creation of a small standing army of cool-headed, courageous soldiers, to be employed not in waging war but solely for defensive purposes, and the development on the part of the soldiers and workers of ability to construct powerful fortifications. It may be said that the formation of the soldier caste as well as the invention of our cement subway architecture—an architecture unsurpassed in magnitude, strength and beauty, considering the small stature of our laborers and the simple tools they employ—was due to the repeated failures, extending over many million years, of our politicians to form a league of nations with our deadly enemies, the ants. After a recent review of the army and an inspection of the fortifications of my termitarium I agree with several of the kings of the present dynasty who believed that we ought really to be very grateful to our archenemies for their undying animosity.

Such was our society at the beginning of the Eocene, and such with slight improvements in detail, it has remained for the past fifty million years, living and working with perfect smoothness, as if on carefully lubricated ball-bearings. Nor does it, like human society, live and work for itself alone, but with a view to the increase and maintenance of other types of life on the planet. On our activities depend the rapid decomposition of the dead vegetation and the rapid formation of the vegetable mould of the tropics. We are so numerous and our operations of such scope that we are a very important factor in accelerating the growth of all the vegetation, not only of the dry savannahs and pampas but even of huge rain-forests like those of the Congo, the Amazon and the East Indies. And when you stop to consider that the animal and human life of the tropics absolutely depends on this vegetation you will not take too seriously the reports of our detractors who are forever calling attention to our destructive activities. One author, I am told, asserts that certain South American nations can never acquire any culture because the termites so quickly eat up all their libraries, and another gives an account of a gentleman in India who went to bed full of whiskey and soda and awoke in the morning stark naked, because the termites had eaten up his pyjamas. How very unfair to dwell on the loss of a few books and a suit of pyjamas and not even to mention our beneficent and untiring participation in one of the most important biocœnoses!

You will pardon me if after this hasty sketch of our history I am emboldened to make a few remarks about your society, and in what I say you will, I hope, make due allowance both for the meagerness of my sources of information and the limitations of my understanding. I must confess that to me your society wears a strangely immature and at the same time senile aspect, the appearance, in fact, of a chimera, composed of the parts of an infant and those of a white-haired octogenarian. Although your species has been in existence little more than one hundredth of the time covered by our evolution, you are nevertheless such huge and gifted animals, that it is surprising to find you in so imperfect a stage of socialization. And although every individual in your society seems to crave social integration with his fellows, it seems to be extremely difficult to persuade him to abate one tittle of all his natural desires and appetites, and every individual resists to the utmost any profound specialization of his structure and functions such as would seem to be demanded by the principle of the division of labor in any perfect society. Hence all the attempts which your society is continually making to form classes or castes are purely superficial and such as depend on the accumulation and transmission of property, and on vocation. And owing to the absence of eugenics and birth-control and to your habit of fostering all weak and inefficient individuals, there is not even the dubious and slow-working apparatus of natural selection to provide for the organic fixation of castes through heredity. So immature is your society in these respects that it might be described as a lot of cave-men and cave-women playing at having a perpetual pink tea or Kaffeeklatsch.

But the senile aspect of your society impresses me as even more extraordinary, because our society—and the same is true of that of all other social insects—is perennially youthful and vigorous, owing to our speedy elimination of the old and infirm. And this brings me to a matter that interests me greatly and one on which I hope we shall have much further correspondence. To be explicit, it seems that though your society has no true caste system, it is, nevertheless, divided into what might be called three spurious castes, the young, the mature and the aged. These, of course, resemble our castes only in number and in consisting of individuals of both sexes. They are peculiar in being rather poorly defined, temporary portions of the life-cycle, so that a single individual may belong to all of them in succession, and in the fact that only one of them, comprising the mature individuals, is of any great economic value to society and therefore actually functions as the host of the two others, which are, biologically speaking, parasitic. To avoid shocking your human sensibilities, I am willing to admit that both these castes may be worth all the care that is bestowed on them, the young on account of their promise and the old on account of past services. And I will even admit the considerable social value of the young and the old as stimuli adapted to call forth the affection of the mature individuals. But, writing as one animal to another, I confess that I am unable to understand why you place the control of your society so completely in the hands of your aged caste. Your society is actually dominated by the superannuated, by old priests, old pedagogues, old politicians and no end of old wowsers of both sexes who are forever suppressing or regulating everything from the observance of the Sabbath and the wearing of feathers on hats to the licking of postage stamps and the grievances and tribulations of stray tom-cats.

I notice that your educators, psychologists and statisticians have much to say on human longevity, and you seem all to crave for nothing so much as an inordinate protraction of your egos. Psychologically, this is, of course, merely another manifestation of your fundamentally unsocial and individualistic appetites. Your writers make much of your long infancy, childhood and adolescence as being very conducive to educability and socialization, and this is doubtless true, but the fact seems to be overlooked that the great lengthening of the initial phases of your life-cycle is also attended by a grave danger, for it also increases the dependence of the young on the adult and aged elements of society, especially on the parents, and this means intensifying what the Freudian psychologists call the father and mother complexes and therefore also an increased subservience to authority, a cult of the conservative, the stable and the senile. The deplorable effects of intensifying these complexes have long been only too evident in your various religious systems and are already beginning to show in the all too ready acceptance on the part of your society of the visionless policies and confused and hesitating methods of administration of your statesmen.

Unless I am much mistaken this matter of the domination of the old in your society deserves careful investigation. Unfortunately very little seems to be known about senility. In our society it can not be investigated, because we do not permit it to exist, and in your society it is said to be very poorly understood, because no one is interested in it till he actually reaches it and then he no longer has the ability or the time to investigate it. When the social significance of this stage in the human life-cycle comes to be more thoroughly appreciated some of your young biologists and psychologists will make it a subject of exhaustive investigation and will discover the secret of its ominous and persistent domination. It will probably be found that many of your aged are of no economic importance whatever, and that the activities of many others may even be mildly helpful or beneficial, but you will find, as we found in the Midcretaceous, a small percentage, powerful and pernicious out of all proportion to their numbers, who are directly responsible for the deplorable inertia of your institutions, especially of your churches, universities and political bodies. These old individuals combine with a surprising physical vigor, a certain sadistic obstinacy which consecrates itself to obstructing, circumventing, suppressing or destroying not only everything young or new, but everything any other old individual in their environment may suggest. The eminent physician who recommended chloroform probably had this type of old man in mind. Certain economic entomologists have advocated some more vigorous insecticide, such as hydrocyanic acid gas. This is, however, a matter concerning which it might be better to defer recommendation till the physiology, psychology and ethology of the superannuated have been more thoroughly investigated.

It has sometimes occurred to me that your social problem may be quite insoluble—that when your troglodyte ancestors first expanded the family and clan into society they were already too long-lived, too "tough" and too specialized mentally and physically ever to develop the fine adjustments demanded by an ideal social organization. I feel certain, nevertheless, that you could form a much better society than the present if you could be convinced that your further progress depends on solving the fundamental, preliminary problems of nutrition, reproduction and social defence, which our ancestors so successfully solved in the late Cretaceous. These problems are, of course, extremely complicated in your society. Under nutrition you would have to include raw materials and fuel, *i. e.*, food for your factories and furnaces as well as food for your bodies. Your problems of reproduction comprise not only those of your own species but of all your domesticated animals and plants, and your social defence problems embrace not only protection from the enemies of your own species (military science) but from the innumerable other organic species which attack your domesticated animals and plants as well as your own bodies (hygiene, parasitology, animal and plant pathology, economic entomology). Like our ancestors you will certainly find that these problems can be solved only by the biologists—taking the word "biologists" in its very broadest sense, to include also the psychologists and anthropologists—and that till they have put their best efforts into the solution your theologians, philosophers, jurists and politicians will continue to add to the existing confusion of your social organization. It is my opinion, therefore, that if you will only increase your biological investigators a hundred fold, put them in positions of trust and responsibility much more often and before they are too old, and pay them at least as well as you are paying your plumbers and bricklayers, you may look forward to making as much social progress in the next three centuries as you have made since the Pleistocene. That some such opinion may also be entertained by some of your statesmen sometime before the end of the present geological age, is the sincere wish of

Yours truly,

WEE-WEE, 43d Neotenic King, of the 8429th Dynasty of the Bellicose Termites.

On reperusing this letter before deciding, after many misgivings, to read it to so serious a body of naturalists, I notice a great number of inaccuracies and exaggerations, attributable, no doubt, to his majesty's misinterpretation of his own and very superficial acquaintance with our society. His remarks on old age strike me as particularly inept and offensive. He seems not to be aware of the fact that at least a few of our old men have almost attained to the idealism of the superannuated termite, a fact attested by such Freudian confessions as the following, taken from a letter recently received by one of my colleagues from a gentleman in New Hampshire:

> I do not understand how it is that an insect so small as to be invisible is able to worry my dog and also at times sharply to bite myself. A vet. friend of mine in Boston advised lard and kerosene for the dog. This seemed to check them for a time, but what I need is extermination, for I am in my eighty-fourth year.

DEFECTS FOUND IN DRAFTED MEN, II

By C. B. DAVENPORT
FORMERLY MAJOR, S. C.
AND
ALBERT G. LOVE
LT. COL., M. C., U. S. A.

14. *Refractive Errors of the Eyes.*—This group of defects is numerically important, having been found in over 30 per 1,000 of the population, a total of about 90,000 men. For the distribution, see Fig. 14. This defect is of great military importance and led to rejection in more than three fourths of the cases. It is of less importance in civil life, since most of the errors are sufficiently correctible to permit a man to carry on ordinary civil occupations. Of the various defects, myopia, short-sightedness, is the commonest. The distribution of myopia is shown in Fig. 15. From this figure it appears that one of the centers of heaviest incidence of errors of refraction is New England and the Middle States. This may be in part due

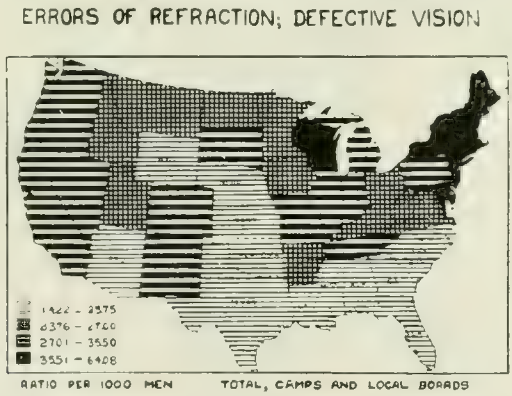


FIG. 14.

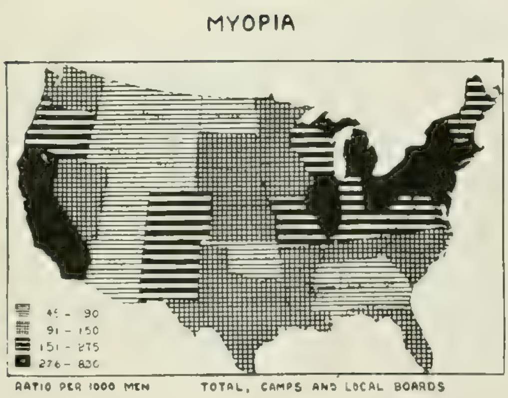


FIG. 15.

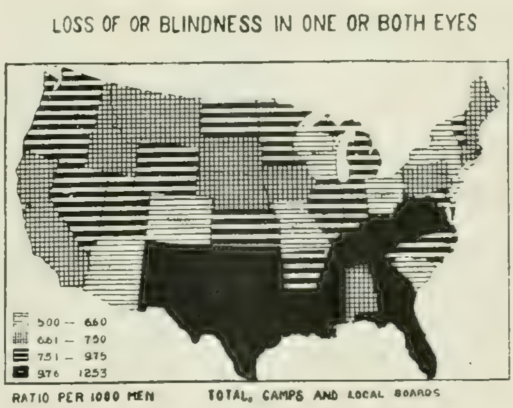


FIG. 16.

to the great care taken by the medical examiners of New England in regard to eye defects. It is, however, certainly very largely due to the presence in New York City and vicinity and in Boston of peoples with a constitutional tendency to myopia. A similar tendency, but less marked, is found in Chicago and in the cities of Ohio and Michigan. Refractional errors are above all a defect of great cities, due primarily to the racial constitution of the population of those cities and secondarily to the overstrain of the eye which comes from clerical and other close work engaged in by a large proportion of the population of these cities. A markedly high incidence of refractive errors is found in those sections containing a large proportion of French-Canadians. The ratio is high also in sections largely occupied by Germans and Austrians.

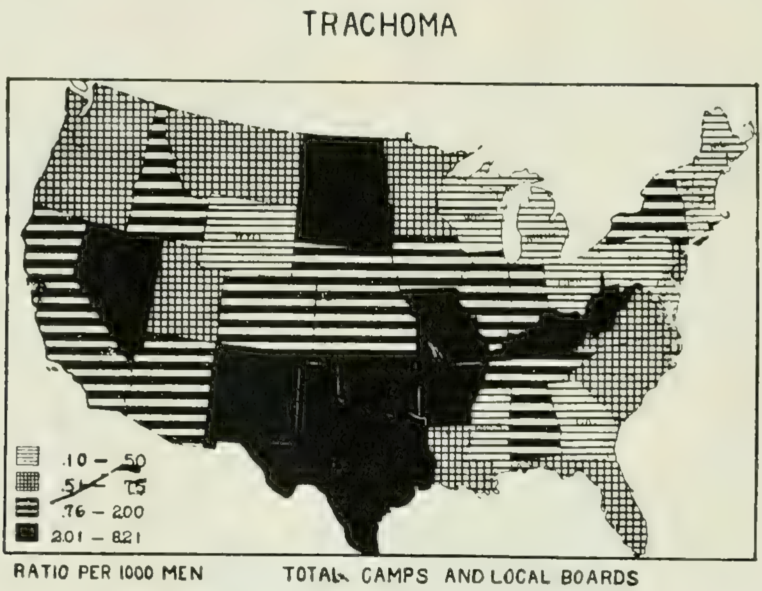
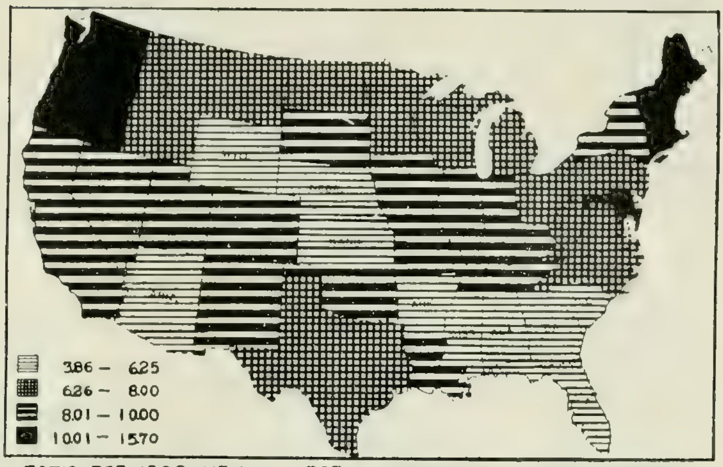


FIG. 17.

15. *Other Eye Diseases and Defects, including Blindness in One or Both Eyes.*—While naturally only a few persons blind in both eyes registered for military service, the number of those blind in one eye was extraordinarily large. There were about 20,000 of them altogether. The distribution is given in Fig. 16, which shows that the center of incidence is in the southern states. This result has probably a combination of causes, such as gonorrhea (which finds its greatest incidence here, and which may blind one eye without affecting the other) and trachoma (Fig. 17), which finds its greatest incidence in the southern states. The extraordinarily large amount of eye defects, other than errors of refraction, in the arid states of the west may well be due in part to the inflammations caused by blazing sun and by dust storms.

DEAFNESS, CONGENITAL OR ACQUIRED

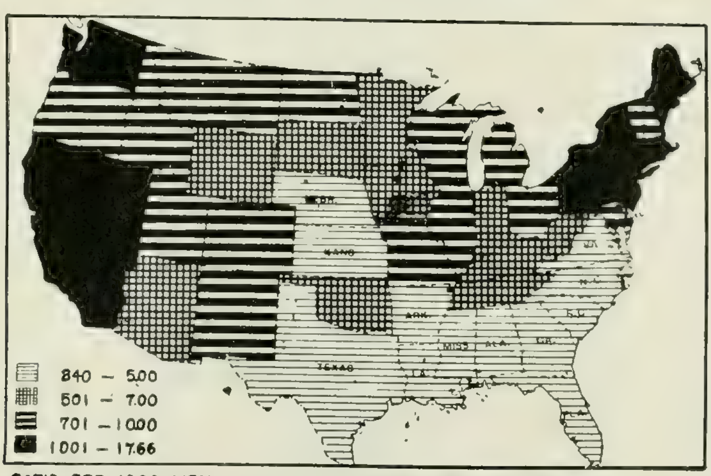


RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 18.

16. *Ear Diseases and Defects.*—Defects of hearing, like all defects of the senses, have a great military importance. In the World War, keen hearing was often a matter of life and death, since, if hearing were adequate, gas shells could be distinguished from others in time to put on gas masks. Defects of hearing have, however, less importance in civil life. The number of persons with ear defects and ear diseases found in the population was great. There were about 22,000 with otitis media, or inflammation of the middle ear, and about 20,000 with defective hearing. The inflammation of the middle ear is a serious matter, since it not only frequently leaves a deafness, but often becomes a center of infection that may cause death. It was a prominent cause of rejection, about 75 per cent. of those with otitis media having been rejected for all military service. The distribution of otitis media is shown in Fig. 18. There are two principal centers, one in the New England and Middle States,

OTITIS MEDIA; PERFORATED EAR DRUM

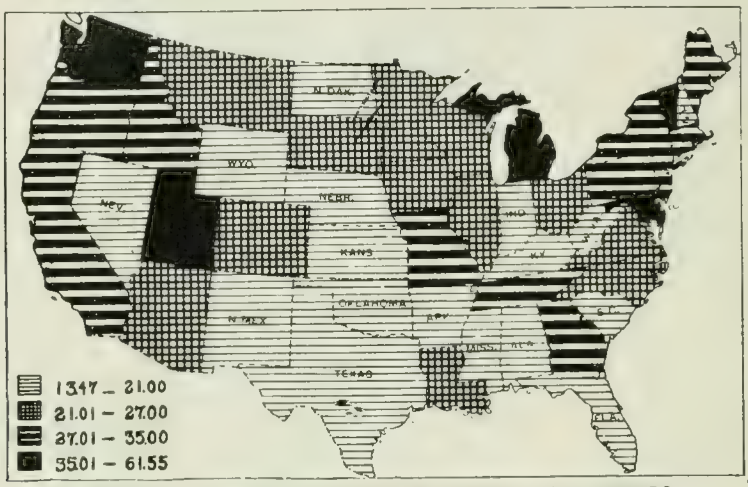


RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 19.

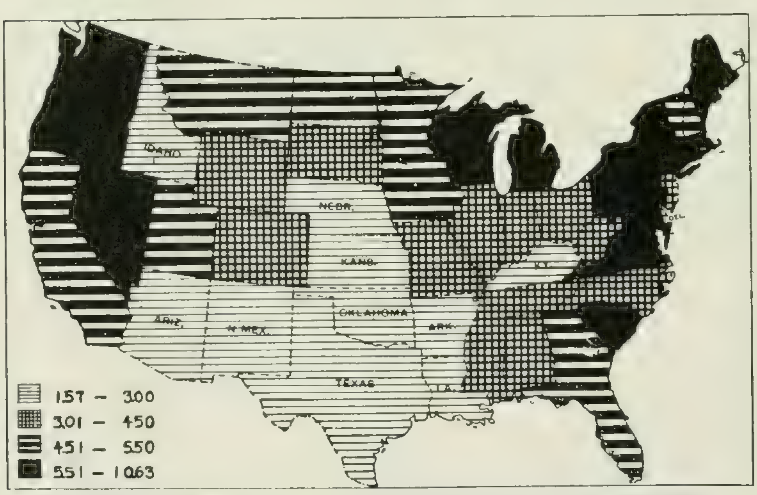
and one on the Pacific coast. The point of greatest incidence is New York City, but other centers of recent immigrants in Rhode Island, New Jersey, and Massachusetts have a great amount of infection of the middle ear. There is a relatively small amount of otitis media in the southern states, a fact that is associated with the comparative immunity from this disease

VALVULAR DISEASES AND ENDOCARDITIS



RATIO PER 1000 MEN REJECTIONS, CAMPS AND LOCAL BOARDS

CARDIAC HYPERTROPHY AND DILATATION



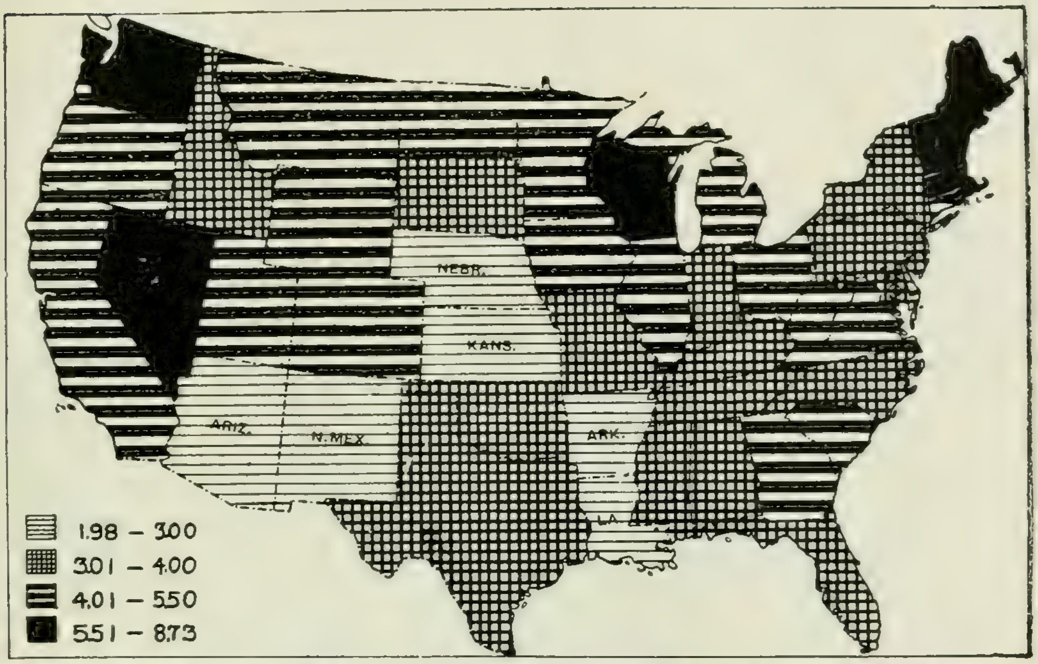
RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 20.

of the negro race. As for defective hearing, distribution of which is shown in Fig. 19, one sees that it reaches a maximum in the New England states. There is, however, a strikingly large amount of it west of the Rocky Mountains, and relatively little in the southern states excepting Louisiana. This exception may be associated with the fact that the French sections to be especially liable to defects of hearing.

1. *Cardio-vascular Defects.*—The statistics on cardio-vascular defects in the drafted men are not altogether satisfactory on account of the difficulty in detecting such defects under the conditions offered during examinations at mobilization camps. There were, however, plenty of defects found; about 5½ per cent. of the men examined had noteworthy defects of the valves or blood vessels. About 10 per cent. of all defects found fall

VARICOSE VEINS

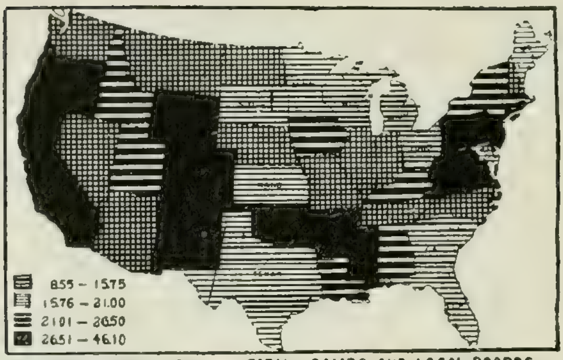


RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 21.

into this category. Of valvular diseases alone over 88,000 cases were recorded and of weak veins about 20,000 cases. Valvular diseases are of great importance from a military standpoint, and only about 7 per cent. of men reported having them were accepted for general military service. Of persons with varicose veins, about 25 per cent. were considered suitable for such service. The distribution throughout the United States of cases of organic diseases of the heart is illustrated in Fig. 20. Two great centers appear, one in the northeastern section of the country and the other along the Pacific coast. Where the disease rate is high in the southern states, it is probably to be associated with the negro population and to some extent with its high infection with venereal disease. Part of the high rate on the Pacific coast is to be ascribed to the idiosyncrasies of the examiners at Camp Lewis, who recorded as defective an undue proportion of men with slight heart murmurs.

TONSILLITIS, HYPERTROPHIC



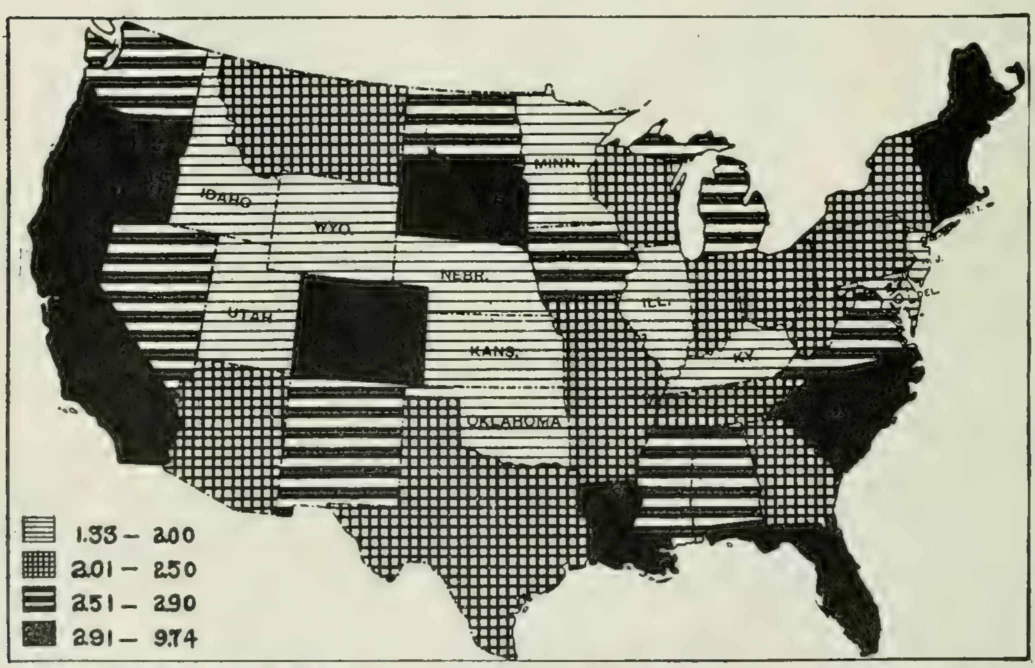
RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 22.

The distribution of varicose veins is shown in Fig. 21. On the whole, this condition is much commoner in the northern states than in the southern and it is found especially in the zone extending from Lake Michigan to the Pacific coast. This is a region of large men belonging to tall races and it is known that these suffer from varicose veins more than do shorter men.

18. *Throat and Nose.*—This highly vulnerable region of the body was found diseased in 65,000 men, few of whom were, however, rejected on this account. The principal trouble was enlarged, inflamed tonsils. The distribution of this condition is shown in Fig. 22. The condition is sometimes ascribed to severe climatic conditions, sometimes to overheated houses, again

ASTHMA



RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 23.

to mechanical irritations like the dust of great cities and of the desert, and again to syphilitic infection. The significance of variations in incidence of tonsilitis in the United States is not clear. It is slightly commoner in cities than in rural districts. The variations perhaps depend in part upon the idiosyncrasies of the examiners at the different camps.

19. *Respiratory Defects (Non-tubercular), especially Bronchitis and Asthma.*—Of non-tubercular respiratory defects, there were recorded over 10,000 cases, chiefly asthma. The distribution of asthma is shown in Fig. 23. As will be seen, its distribution is highly irregular. It is found especially in the

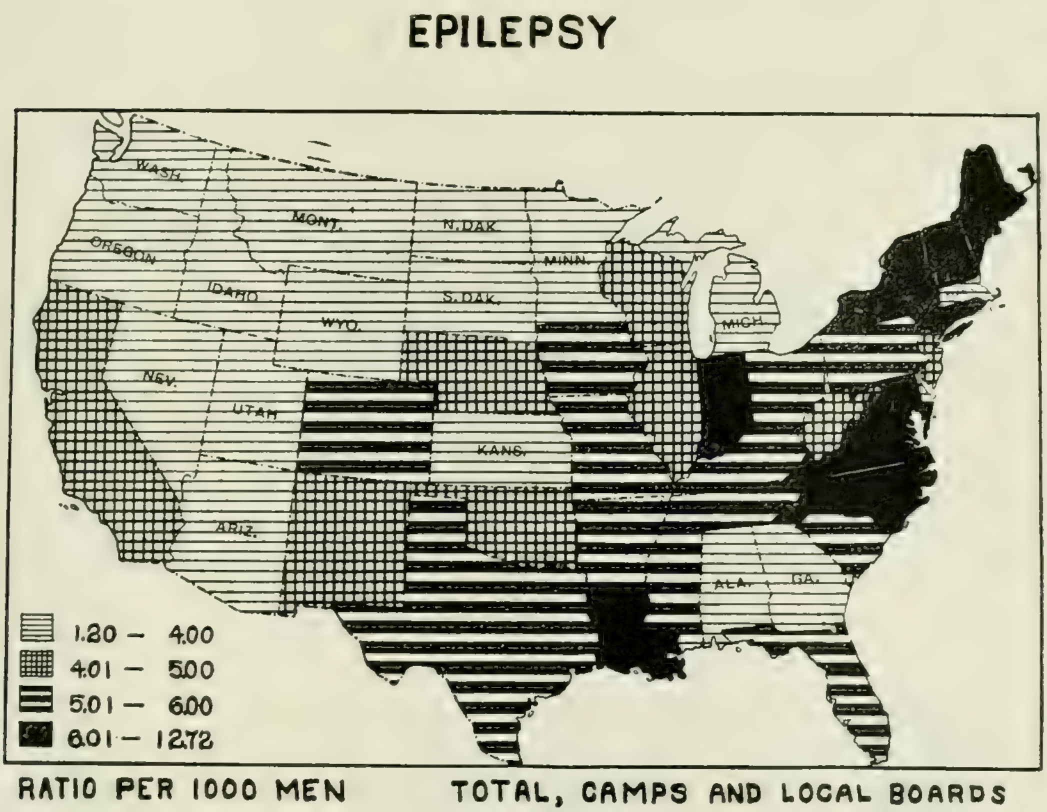


Fig. 24.

north. The entire New England states are involved and the Pacific coast is one of high incidence of the disease. It is fairly common in the black belt of the south. French-Canadians show it more than others, but beyond this there is little evidence that any special race is especially susceptible to or immune from it.

20. *Nervous and Mental Defects.*—To this great group there were assigned about 6 per cent. of the defects found, giving a rate of 33. The two commonest types were epilepsy and mental deficiency. There were over 14,000 cases of epilepsy, giving a rate of 5. The disease is especially prevalent in rural districs, probably in consequence of the greater amount of inbreeding there. The distribution of epilepsy by states is shown in Fig. 24.

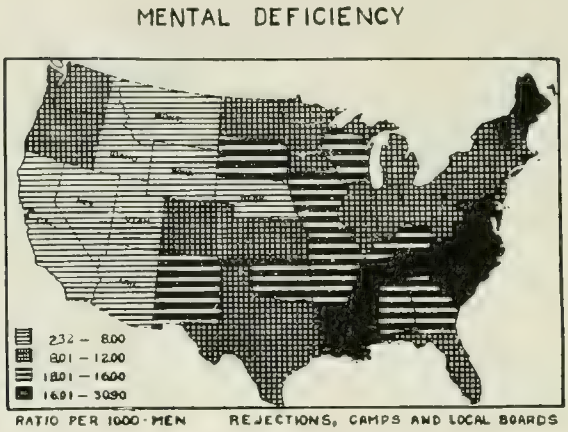
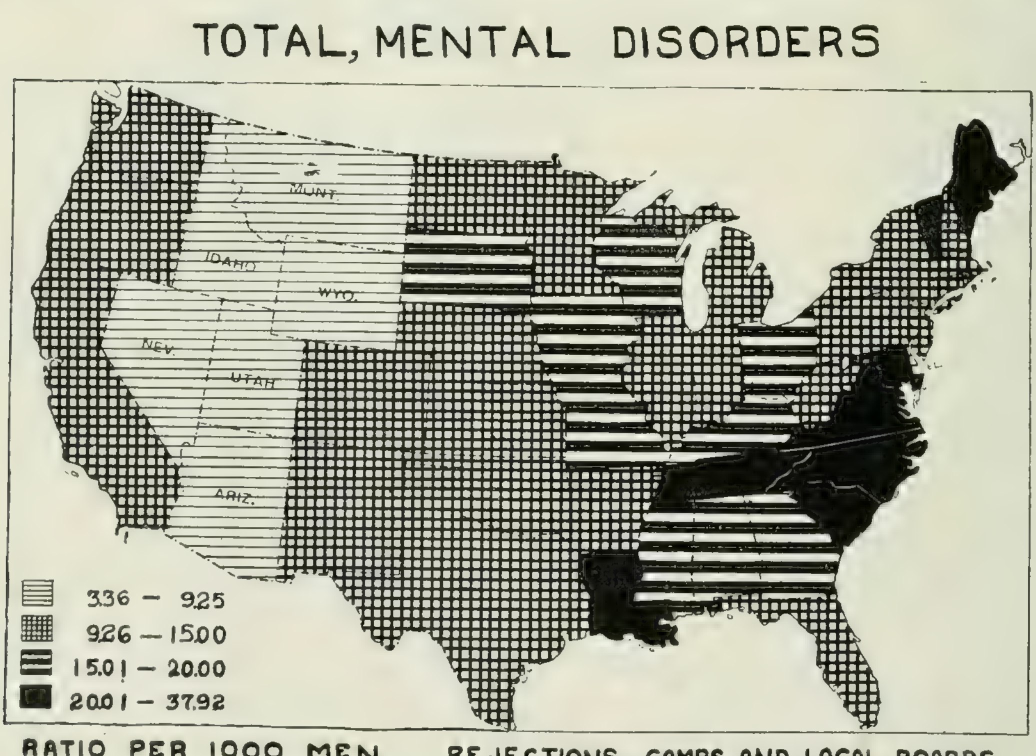


Fig. 25.

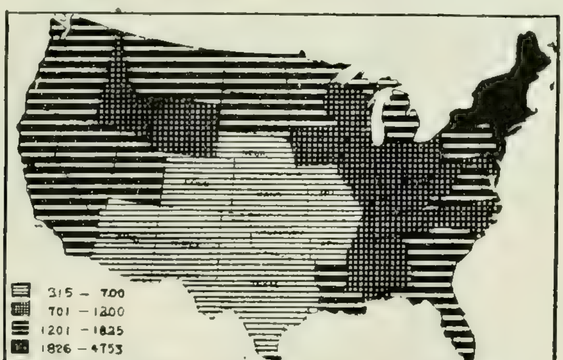
It appears at a glance that it is commoner in the older-settled parts of the country, New England, New York, Virginia, North Carolina and Louisiana. The northwest is relatively free from it, and this is no doubt due to the immigration of persons without the defect to the west and to the outmarrying that has occurred there. For it is well known that inbreeding of epileptic stock increases the incidence of the defect in the population. The disease is especially common in the districts where there are many French-Canadians. It is probably widespread among the French as a race, which may account for the high rate in Louisiana.

Mental deficiency was recorded in about 40,000 cases, giving a rate of 14. This does not give a complete picture of the



amount of mental deficiency of men of military age, because still additional cases were later discovered by the method of psychological examination. Mental deficiency, like epilepsy, is especially common in rural districts. The map of its distribution is given in Fig. 25 and Fig. 25*a*, which show that it is especially common in older-settled parts of the country and there is more of it in the southern states than in the northern. This excess in the south is, of course, largely due to the negro race. The comparative absence of mental deficiency in the west is doubtless due to the fact that few mentally defective persons have immigrated there. The commuter group contains the lowest rate among the occupational groups, while the mountain whites comprise the highest. One of the surprising results of the draft examination is the large amount of mental deficiency and backwardness among the southern Allegheny Mountains.

DEFECTIVE OR DEFICIENT TEETH; DENTAL CARIES



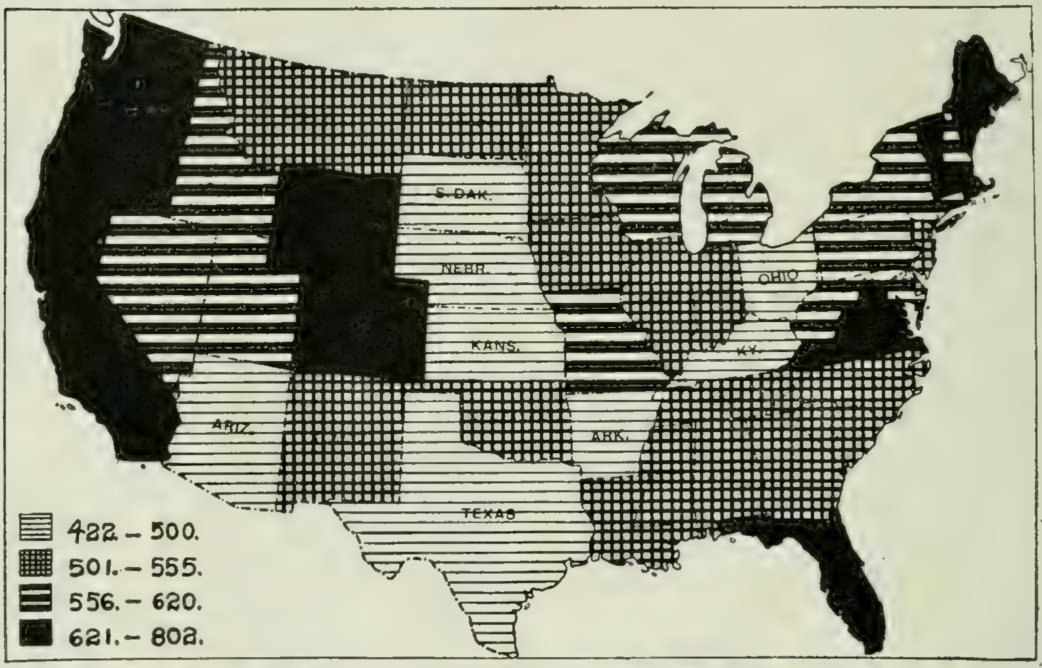
RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 26.

21. *Teeth.*—Defective teeth are noted in 37,000 men. It is clear that only the grosser defects were recorded. The recorded defects were indeed so gross as to lead to rejection in about 70 per cent of the cases. It is clear that the requirements for Army life are higher than those for civil life. The distribution of defective and deficient teeth is shown in Fig. 26. The one great center for defective teeth is the extreme northeast, including the New England states, New York and New Jersey. The second center is in the northwest, including states next to the Canadian border and those on the Pacific slope. A comparative freedom from defective teeth is found in the prairie states and those of the southwest. Defective and deficient teeth are much commoner in cities than in rural districts, despite the better provision for their care in the cities. This may be in part due to conditions, but it has more probably chiefly a racial significance. There is a large amount of defective teeth among the

colored people (despite a high natural resistance to dental caries among full-blooded negroes) and there is probably a racial lack of resistance in the old English stock that settled New England. On the other hand, the sections largely occupied by Indians and Mexicans show an exceptionally low rate of defective teeth, while those sections largely occupied by French-Canadians show the highest rate.

DISEASES OR DEFECTS BY STATES



RATIO PER 1000 MEN TOTAL, CAMPS AND LOCAL BOARDS

FIG. 27.

IV. Comparison of Incidence of Total Defects in the Various States

The distribution of total defects and diseases in the different states is shown in Fig. 27. Also detailed ratios are set forth in Table 1. There are two great centers of defect—one is in the northeastern part of the United States, and the other in the western half, including especially the states on the Pacific coast and the two mountain states of Wyoming and Colorado. Of all states Rhode Island leads with a defect rate of 802. This high defect rate, like that of the other New England states, is largely controlled by flatfoot and hernia. In the case of Rhode Island, however, many minor defects find here the maximum or nearly the maximum ratio. Conditions in which Rhode Island stand first or second are: Alcoholism, obesity, neurosis, total for myopia and defective vision (cause not stated), hemorrhoids, bronchitis, deformities of appendages and trunk, atrophy of muscles of the extremities, underheight and underweight. The reason why Rhode Island stands at or near the top in many defects is largely because of the defective or non-resistant stock which has been drawn to this, the most urban of all states—that in which the population is most generally engaged in manufacturing. While one may not ascribe the defects to the occupation, it is probable that the relatively low-grade, ill-paid occupation has attracted a stock with inherent defects or susceptibility to disease.

Next to Rhode Island stands Vermont with a defect rate of 764. It is surprising in what a number of defects the small state of Vermont leads. The reason for this is probably the presence of a large number of French-Canadians, in whom the defect rate it particularly high. The third state in the list is Virginia with a defect rate of 734. This state, one of the first settled in the country, apparently suffers in part from its age and consanguineous matings and in part from the nature of its colored population. Virginia stands among the first six states in the following defects: Speech defect, deafness, mental deficiency, mental alienation, sinusitis (or inflammation of the cavities of the head), enlarged tonsils, hypertrophied or dilated heart, cardiac arrhythmia (irregularities of the heart), tachycardia (rapid heart), total for hernia and enlarged inguinal rings, mal-union of fractures of upper and lower extremities, hammer toe and hallux valgus, pronated foot, pes cavus (contracted foot) and foot deformities not specified, metatarsalgia (painful foot), bullet or other recent wounds, and grand total for me-

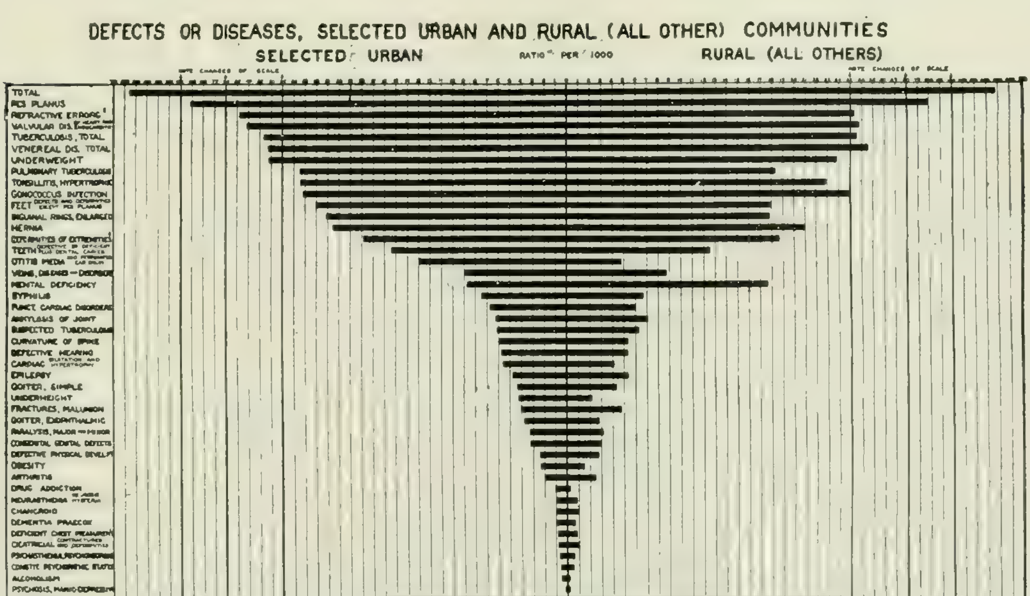


FIG. 28.

chanical defects. Many of these defects are congenital, such as arise in a highly inbred population. Others seem to be due to bad conditions of living, such as are associated with mental defect. Another large number of them is due to infection with the microorganisms of venereal disease.

At the bottom of the list stands the state with the lowest defect rate, Kansas, in which there were 422 per 1,000, only a little more than one half the defect rate for Rhode Island. Near the bottom of the list stand South Dakota, Nebraska, Kentucky, and Arkansas. These are states which have received a small amount of the more recent immigration from southeastern Europe. They are prevailingly white agricultural states (except certain parts of Arkansas, which has a rather high colored rate). This list, however, serves to warn that the influence of camp examiners has a considerable effect upon the final ratio and it is to be kept in mind that Kansas, Nebraska, South Dakota men were all examined at Camp Funston, while men from Arkansas were examined at Camp Pike. At both these camps there is reason to believe that the physical examinations were somewhat inferior in quality, so that the proportion of defects recorded to defects in registrants was less than in many other camps. This inferiority in the examiners is, however, much more striking in the case of Pike than in the case of Funston; and we must believe that the comparative freedom from defect in the states lying just east of the Rocky Mountains from South Dakota to Texas corresponds to a real physical superiority.

Since not all defects are causes for rejection, there has been made a separate table, No. 3, showing the distribution of causes of rejection by states. Here also Rhode Island stands at the top with a ratio of 424. This implies that perhaps 40 per cent. of the registrants examined in Rhode Island had to be rejected for all military service. Considering the distribution of rejections as shown in the table, it will be noted that they lie chiefly along the Atlantic and Pacific seaboards and are relatively uncommon in the interior of the country, particularly west of the Mississippi River. The New England states, New York and Michigan show a high rate for rejection. There is a considerable amount in Georgia and Tennessee (both examined at Camp Gordon), a large proportion from California and Washington, partly due to tuberculosis in the first case and various injuries in the second, and also in Louisiana. In the states west of Mississippi, however, we find low rejection rates, such as in Wyoming where less than 13 per cent. of defects found were cause of rejection.

Similar results were obtained in Nebraska, Kansas, Arizona, Montana, Arkansas and North Dakota; the inhabitants of these states are clearly a relatively physically fit lot. They represent a selection of the most vigorous of our population. On the other hand, the east seaboard has suffered by the loss of these fine young men who have migrated to the west, while those who are physically defective have more largely remained at home in the east. Also many immigrants of physically less fit stock have remained near the ports at which they have arrived from Europe, while representatives of the physically better developed races have migrated west.

For the purpose of securing populations of greater homogeneity, some of the larger of the forty-eight states were divided into two or more sections. The defect rates for these sections are often more varied than those of the states. The highest rate found outside of the state of Rhode Island is Section 5 of Colorado, which is the city of Denver. This had a rate of 800. This high total rate comprises certain large separate rates like the following: Tuberculosis 122, defective vision 35, hypertrophied tonsils 27, hernia 49, flat foot 184, and underweight 40. The lowest rate of any section is Section 1 of Kansas, which includes a strip along the Arkansas River in western Kansas. Here the rates for the diseases which we picked out in Colorado for their great size appear relatively small: Tuberculosis 12, defective vision 19, hypertrophied tonsils 12, hernia 18, flat foot 104, and underweight 1. Thus, it is seen that the reason why Colorado has such a high defect rate is because of the higher rate for tuberculosis, underweight, hypertrophied tonsils and flat foot, all of which may be dependent on infection with *Bacillus tuberculosis,* whereas the low rate for Kansas and Nebraska is due to the low rate in these conditions as well as in some others. In the case of Rhode Island, which has even a higher defect rate than Section 5 of Colorado, namely of 802, the tuberculosis rate is small, 21, and the rate for flat foot is only 117, but, on the other hand, many of the rates for the selected defects are larger than in Colorado and there are many others which have a high defect rate in Rhode Island. Thus, defective vision has a rate of 57; underweight 93; mental deficiency 16; valvular lesions 34; bad teeth 42; underheight 12. Thus, the high rate in Colorado is primarily a high rate due to the selective gathering there of persons affected with latent or active tuberculosis, while the high defect rate in Rhode Island is due to small size and a number of defects indicative of poor stock and poor conditions of life. All fluctuations in defect rates of the different sections have in this way a meaning; but it is impossible to discuss the variations in this paper.

Consolidation of Similar Sections.—The 156 sections were brought together into 22 groups. These fall into three series, an agricultural series, a physiological series and a racial series. For the different groups the ratio of defect found varies considerably. Thus, in the northern agricultural groups, it is about 530, in the white agricultural group of the south, 520, in the negro agricultural group, 500, in the eastern manufacturing group the rate rises to 590 while the commuter group has a ratio of less than 540. In the mining group the rate is 569, in the sparsely settled group of the southwest it falls to 470. In the desert group, including among others, Nevada, Arizona and New Mexico, the rate is relatively high, 670. This is largely because of tuberculosis, underweight and flat foot. In the maritime group the rate is 685; in the mountain group, 570; in the sections occupied largely by Indians the rate is relatively low, 530; and still lower in the Mexican section, 470. The "native whites of Scotch origin" is a name applied to a group comprising two sections, with a rate of 473. Of the remaining areas in which one race constitutes over 10 per cent., Russians have a rate of 590; Scandinavians of 543; the Finn section a rate of 520; the French-Canadian section a rate of 684. Finally, there are three groups of German, Scandinavians and Austrians combined in various proportions in which the rates run between 510 and 540. Thus, of all the agricultural groups the rate is lowest for the negro group. In the occupational series it is highest in the manufacturing group. It is remarkably high in the desert group on account of tuberculosis and throat diseases. It is low in the groups containing a large proportion of Finns, Russians and Scandinavians, still less in the sections containing a large proportion of Indians and Mexicans. Too much stress must not be laid upon the totals. Of interest, however, is the comparison of the relative frequency of the particular diseases in each group.

The occupations play a rôle in the distribution of defects. Bad postures at school, especially in the badly nourished and rickety, account for much of the curvature of the spine, and this is developed especially in the cities; standing in shops and walking on pavements in tight shoes account for many of the bad feet of city folk. Much school and clerical work tend to induce myopia in those so disposed. Probably dust, other irritants and uncleanliness of crowded quarters favor nose, throat and ear inflammations in those predisposed. Straining the body by heavy work induces hernia; mill work in the south and lumbering in the north causes loss of upper extremities; lumbering and saw-mill operation cause loss of fingers and arms and railroading causes injury to legs. Agriculture is associated with good eyes, straight backs and in the south (but less in the north) with freedom from flat foot and distorted toes. The eastern manufacturing group is characterized by an excess of myopia, valvular diseases of the heart, speech defect, bad teeth and underweight. On the other hand this group has a small amount of hernia and blindness of one eye. The commuter group is characterized, like the eastern manufacturing group, by myopia, also by an excess of otitis media; but the rate for tuberculosis and mental defect is exceptionally low. The commuter group represents the physically fittest of the population of the eastern section of the country. The group containing a large proportion of mining population is characterized by a fairly high rate of venereal diseases and by much tonsillitis, but relatively few cases of underweight.

Of the agricultural groups the negro sections are characterized by an abnormally high amount of venereal disease and its sequelæ, such as valvular heart disease, arthritis and ankylosis, by hemorrhoids, by poor emotional control, including tachycardia, hysteria and psychasthenia, by relatively little otitis media, deafness and defect of vision (though by much blindness of one eye), by little diabetes, spinal curvature, cryptorchidism, flat foot, and by many bullet and other wounds.

The Scandinavian sections are characterized by a slight amount of venereal disease, by relative freedom from hallux valgus and by much flat foot and by a tendency to hernia. The German groups are characterized by neurasthenia, psychoneuroses, and various psychoses, but by relatively little mental deficiency; by an excess of myopia and curvature of the spine. The French-Canadian group shows an extraordinary excess of various important defects, such as tuberculosis, spinal curvature, deaf mutism, mental deficiency and psychoses, refractive errors, otitis media, defective hearing, asthma, bad teeth, hernia, deficient size of chest and underheight and underweight. The sections of which the French-Canadians form a predominant factor are among the poorest from the military standpoint.

The groups occupied largely by Indians and Mexicans are characterized by a large amount of tuberculosis, venereal disease, and ankylosis and a low rate of valvular diseases of the heart and deformities of the hand.

The mountain whites constitute a sub-race of the whites occupying the southern Allegheny Mountains. They are characterized by an exceptionally high proportion of mental defect and mental disease, by varicose veins, by numerous deformities of the extremities and by underweight.

Various physiographic regions differ in their characteristic defects. We may distinguish the maritime, mountain, desert and sparsely settled areas. The maritime district, apart from the great cities, includes a high defect rate for venereal disease, for various nervous and mental diseases, myopia, valvular diseases of the heart, myocarditis, arteriosclerosis, flat foot, hallux valgus, deficient teeth and underweight. This group is largely influenced by conditions in the parts of Virginia bordering on Chesapeake Bay, as well as in the peninsular regions throughout the north. There is, on the other hand, a comparative absence of goiter and drug addiction.

The mountain sections, on the other hand, are characterized by goiter, deficient vision, valvular diseases of the heart, acquired defects and bad teeth, while there is relatively a small amount of tuberculosis, venereal disease, myocarditis, tonsillitis, arteriosclerosis and deaf mutism.

The desert region is characterized first of all by tuberculosis (due to the use of this region as a sanitarium), by hernia, trachoma, and flat foot and by a small amount of myocarditis, defective speech and bad teeth. The sparsely settled regions of the northwest, outside of the desert territory, are characterized by high rates of goiter, hernia, flat foot and deformities of the hand resulting from accident. On the other hand, there are low rates for nervous and mental disease, for eye defects, otitis media and underweight.

These results are not to be interpreted as indicating merely the effect of conditions upon physique; they are largely controlled by the constitution of the populations which have selected these regions as homes.

Comparison of Rural and Urban.—The whole country has been divided state by state into rural and urban districts. The statistics reveal a rural rate of 528 and an urban rate of 609. Thus, the selected cities showed about 15 per cent. more of defects than did the rural districts. This excess of urban defects is largely determined by the excess of flat feet, which amounts to a rate of 25. There is also in the cities an excess of underweight, inflammation of the middle ear, errors of refraction, goiter, pulmonary tuberculosis, defective teeth, and syphilis.

These defects, in which the city rates surpass the rural rates, are, however, partly counterbalanced by the greater amount in rural districts of mental deficiency, deformed and defective extremities, blindness in one eye, arthritis and ankylosis and gonococcus infection. Thus, while the urban districts exceed in the defects due to inferior stock and bad environmental conditions, the rural districts exceed in hereditary congenital defects (partly due to the fact that many congenital defects increase in the population in consequence of consanguineous matings, which are commoner in the rural districts than in great cities) and to accidental injuries (also in the amount of rural negro gonorrhea). The relative incidence of various defects in urban and rural districts is shown graphically in Fig. 28.

Thus, in summary, the northeastern part of the country appears to be characterized by congenital defects and those of city life. The northwest is characterized by deformities due to accidents, by goiter and by flat foot. The southeast is characterized by venereal diseases, hookworm and similar complications, including blindness of one eye, arthritis and ankylosis, underweight, mental defect, emotional disturbances, by pellagra, hernia, loss of upper extremity, and bullet and other wounds. The southwest is characterized by tuberculosis, drug addiction, hypertrophied tonsils and hernia. The northern central area is contrasted with the southern central by having more goiter, less tuberculosis, much less venereal disease, more varicocele and more varicose veins, more valvular disease of the heart and cardiac hypertrophy and dilatation, more deficient teeth, more psychasthenia and constitutional psychopathic states. It is characterized by more otitis media, errors of refraction, diabetes, curvature of the spine, defects of genitalia and weak feet, but less epilepsy, blindness of one eye, pellagra, loss of upper extremity, bullet and other recent wounds, underweight and deficient chest measurement. From a military standpoint the northwest contains the best men of the country.

TONE COLOR

By Dr. T. PROCTOR HALL

VANCOUVER, B. C.

AT ordinary temperatures, waves of sound in air advance at the rate of 340 meters (1,120 feet) per second. By wave-time is meant the time of advance from a given position to the position of the preceding wave. It is recognized by the ear as the pitch of the tone. Wave-length, the distance between the crests of two consecutive waves, is the product of the velocity and the wave-time. The wave-length of audible sounds in air varies from one centimeter for the highest to twenty meters for the lowest note. Sounds whose wave-lengths are less than a centimeter are not heard by human ears. Sounds with waves longer than twenty meters are heard as a series of beats, but not as a continuous note. The wave-time of middle C on the piano is 39 ten-thousandths of a second.

FIG. 1. DIAGRAM OF A SOUND WAVE IN AIR. Wave-length, one centimeter. Wave-time, 0.3 ten-thousandths of a second.

The loudness of the sound depends upon the amount of energy contained in its wave. For waves of a given pitch and quality this increases with the amplitude, that is, with the extent of motion of the air-particles during the passage of the wave.

Sound waves are impressed as up-and-down indentations on a graphophone cylinder or an Edison disk, and as side-to-side wavy grooves on the ordinary disk of a gramophone. They are conveniently and clearly represented on paper as up-and-down waves proceeding from left to right, in which the down part of the wave indicates compression and the up part expansion of the air.

The simplest form of a wave is the sine curve (Figure 2). Its tone is smooth and clear, like the tone of a tuning fork or a flute. Many instrumental waves are compound sine curves,

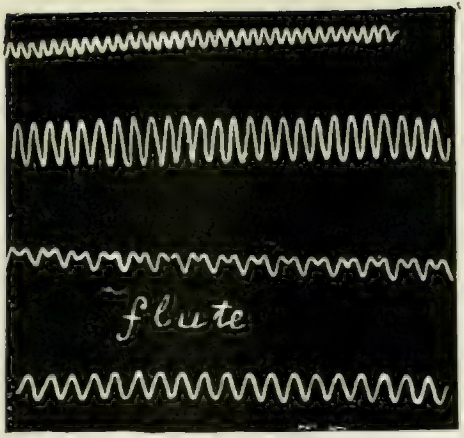


FIG. 2. FLUTE WAVES, ENLARGED FROM A GRAPHOPHONE RECORD. Magnified vertically 2,000 times. Each line is made by a single note.

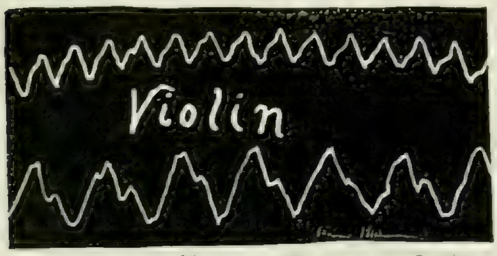


FIG. 3. VIOLIN WAVES, × 2,000.

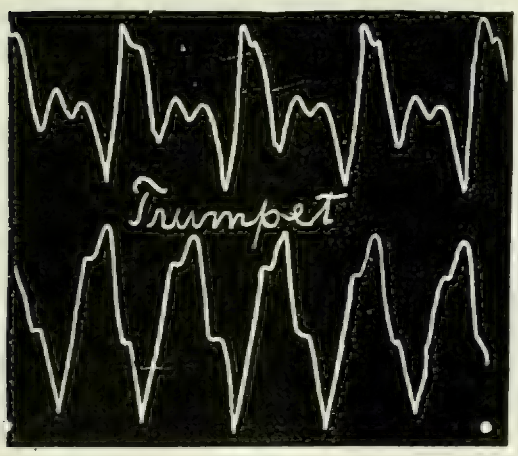


FIG. 4. TRUMPET WAVES, × 2,000.

FIG. 5. WAVE FROM A LOW NOTE OF A TROMBONE. The whole curve between the sharp upper points is a single wave. × 2,000.

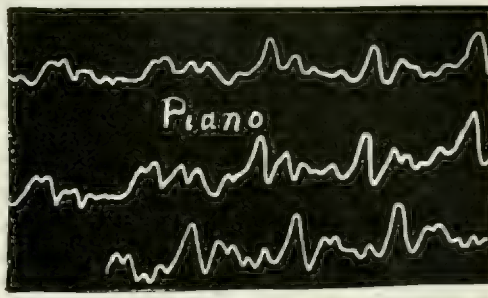


FIG. 6. PIANO WAVES, × 2,000. The first two lines are two successive tracings over the same wave-record, given to show the degree of accuracy of the enlarging machine.

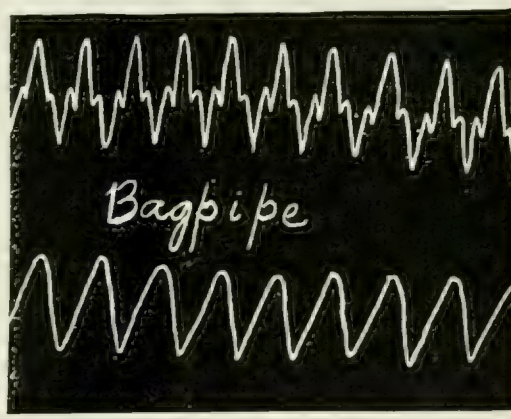


FIG. 7. BAGPIPE WAVES. The upper line, like the third line in figure two, shows a compound note. × 2,000.

consisting of a fundamental long sine wave, to which are added shorter sine waves whose lengths are submultiples of the first. The form of these compound waves gives to each instrument its characteristic timbre or quality, by which, for example, the note sounded by a violin is distinguished from a note of the same pitch and loudness made by a cornet.

Notes sung by a human voice differ radically from such instrumental notes, in that their smaller superposed waves have no fixed ratio to the fundamental wave. In the voice the fundamental wave, which decides the pitch of the vocal note, is produced by a rapid succession of puffs of air forced from the lungs through the slit between the closed and stretched vocal cords.

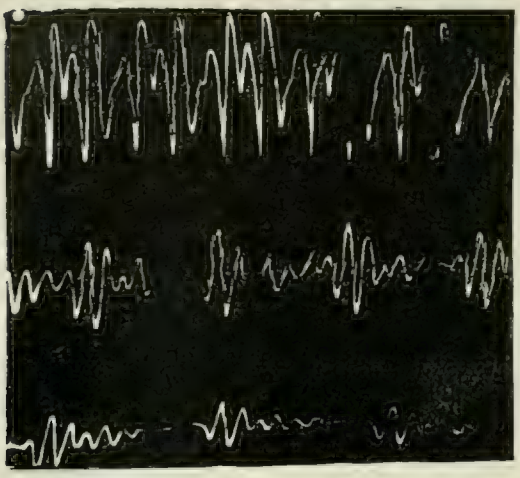


FIG. 8. THE SOUND OF *a* IN HAT, ×2,000. The upper line shows 5 or 6 wave groups, of moderate pitch; the second is a low note; the third very low, with long wave groups.

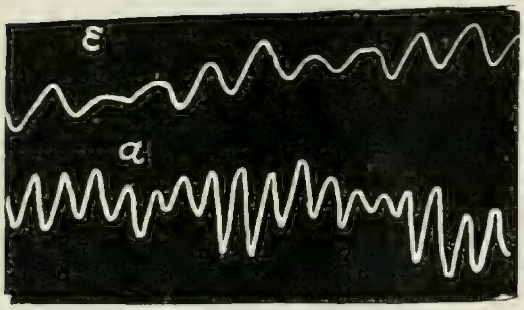


FIG. 9. THE LOWER LINE SHOWS A VERY LOW NOTE OF *a* IN HAVE: THE UPPER A LOW NOTE OF *a* IN MADE. ×2,000.

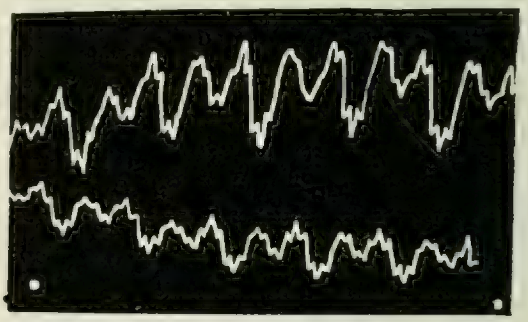


FIG. 10. WAVES OF *ee* IN DEEP. ×1,200.

Tightening the cords increases the rate of the puffs and therefore raises the pitch. Following each puff the air in the throat, nose and mouth is thrown into more rapid oscillation, like the air in an organ pipe; and these smaller resonance waves, which are added to the pitch wave, are the source of the different vocal qualities. Vowel quality, for example, depends on the lengths of the resonance waves present. The short sound of *a*, as in "hat," has a resonance wave-time of 14 ten-thousandths of a second. The long sound of *a*, as in "made," has 24 ten-thousandths. The sound of *ee* in "deep" has two resonance waves; one whose wave-time is 1½, the other 20 or more, ten-thousandths of a second.

The term tone color is sometimes used to express timbre, or tone quality of any kind. I propose to restrict its use here to that kind of tone quality which is independent of the form, amplitude, time, or length of the wave.

The tone colors of the notes of the diatonic scale have been variously described. One set of descriptive words is so selected as to begin with the same letters as the names of the notes to which the words apply. Another set is similarly related to the letters on the staff in the scale of C.

do′	defiant	C′	Clearness
ti	trying	B	Brightness
la	lurid	A	Adversity
so	strong	G	Gladness
fa	fateful	F	Faith
mi	mild	E	Ease
re	rousing	D	Desire
do	dauntless	C	Constancy

These diatonic colors were personified by a young lady teacher, for the benefit of her younger pupils, in the story of

THE DO FAMILY

When they receive visitors at their home by the C the members of this family always sit in a row in their parlor. First comes Father Do, next to him a husky boy Re, and his little sister Mi. Beside Mi sits her melancholy brother Fa, and next to him the big brother So. Grandma La comes next and helps to look after Baby Ti, who always keeps close to Mother Do.

The diatonic colors whose nature is suggested by these various expressions are unchanged by a change of the key. It follows that they are due to the relation that each note bears to the key note. What this relation is will now be shown.

A stretched string or a column of air vibrating as a whole gives out its lowest or fundamental tone. If it vibrates as two separate halves the note is an octave higher and the wave-time is one half as great. If it vibrates in three equal lengths the note is *so* in the next higher octave, and the wave-time is one third. Proceeding in this way we obtain a series of notes from which a selection is made to form a "natural scale." The notes of the diatonic natural scale have the wave-times and wave-lengths, relative to the lowest note, given in the first line of fractions below.

do	re	mi	fa	so	la	ti	do
1	$8/9$	$4/5$	$3/4$	$2/3$	$3/5$	$8/15$	$1/2$
	$8/9$	$9/10$	$15/16$	$8/9$	$9/10$	$8/9$	$15/16$

The second line of fractions gives the ratio of the wave-time of each note to the one before it. From this it appears that there are three kinds of intervals between the notes. Two of them, $8/9$ and $9/10$, are nearly equal; the third, $15/16$, is about half as great as either of the others.

If a piano or organ were tuned to the natural diatonic scale all the music played on it would have to be played in the key of C, or the intervals would not fit the music. A change of key would not be possible.

To overcome this difficulty Bach, 200 years ago, devised the Tempered Chromatic scale, in which each octave is divided into twelve equal intervals, or twelve tempered chromatic *tones*.[1] The wave-times of the several notes of this scale are found from the time of the key note by dividing repeatedly by the twelfth root of 2 (=1.0495).

The following table shows the relation of these notes to each other, and also to the notes of the natural diatonic scale. It will be seen that *do, re, fa* and *so* are practically identical in the two scales, and that the difference of wave-time for *mi, la* and *ti* is in each case less than one per cent.

Diatonic Natural Scale			Tempered Chromatic Scale		
Note	Ratio to Keynote		Tones Above Key	Ratio to Key	Approx. Simple Fraction
do′	1/2	.5	12	.5	1/2
ti	8/15	.533	11	.530	9/17
—			10	.561	9/16
la	3/5	.600	9	.595	3/5
—			8	.630	5/8
so	2/3	.667	7	.667	2/3
—			6	.707	12/17
fa	3/4	.750	5	.749	3/4
mi	4/5	.800	4	.794	4/5
—			3	.841	5/6
re	8/9	.889	2	.891	8/9
—			1	.944	17/18
do	1	1.000	0	1.000	1

The strongest note, *so,* of the diatonic scale bears the simplest time-ratio, ⅔, to the key note. The note next in strength, *fa,* has the ratio, ¾, next in simplicity. The most complex ratio, 8/15, belongs to the note *ti* whose tone color is irritation or unrest. Next to *ti* is *re,* 8/9, whose tone color is stronger, but partakes of unrest because of the psychic effort required to appreciate the element of harmony in the ratio of 8 to 9. Evidently the diatonic color of each note of the scale is determined by the ratio its wave-time bears to the wave-time of the key note. During a melody the key note is subconsciously borne in the memory, and each note that is sung is subconsciously compared with it. A change of key makes a corresponding change in the note of reference and shifts the diatonic colors to the new position of the scale.

[1] Musicians still persist in calling these intervals "half tones," which is as foolish as it would be to call the unit of length a "half meter."

The diatonic color of a note is therefore determined by the interval between it and the key note. It is evident that any interval between successive notes of a melody must in the same way produce in the second note a tone color, which I shall call melodic color. The melodic color of a note may be stronger than its diatonic color and may either reinforce, modify, neutralize, or even reverse the diatonic color. Melodic colors occur in all possible chromatic intervals, and all these intervals are found between notes of the diatonic scale. The following table gives the tone color of each chromatic interval, the words being suggestive rather than exactly descriptive.

Note	Interval	Tone Color
do	12	Boldness, defiance.
ti	11	Suspense, restlessness.
	10	Awe, dread.
la	9	Apprehension.
	8	Pleasure.
so	7	Brilliance.
	6	Strangeness.
fa	5	Depth of feeling.
mi	4	Agreeable mildness.
	3	Sorrow, depression.
re	2	Anger, resentment.
	1	Irritation.
do	0	Confidence, rest.

Melodic color exists not only between the successive notes of a melody but to some degree between any two of its notes. The accented notes form, by themselves, through their diatonic and melodic colors, a skeleton which expresses the stronger characters of the melody. The color of a musical phrase may be so pronounced that its essential character is retained in various positions on the scale. Here are the endless possible combinations in which composers revel, guided by a sense of feeling, often with no clear consciousness of the elements of their art.

A third variety of tone color, which may be called harmonic, arises from the relation of the upper note of a common chord to its ground note. The ground note is already in the subconscious memory in relation to the key note, and the upper note adds to its other colors some of the color of the ground note. The middle note of a major common chord is the upper note of its relative minor, and its harmonic color is that of the ground note either of the minor or of the major weakened.

				Relative Wave-times	
Tonic chord	do	mi	*so*	15: 12: 10	
Its relative minor........la	do	*mi*		6: 5: 4	
Subdominant chord	fa	la	*do*	15: 12: 10	
Its relative minor........re	fa	*la*		6: 5: 4	(nearly)
Dominant chord	so	ti	*re*	15: 12: 10	
Its relative minor........mi	so	*ti*		6: 5: 4	
Dominant seventh .... .so	ti	re	*fa*	15: 12: 10: 8½	(nearly)

Each chord has its own chord color, which is totally distinct from its harmonic quality, and is, speaking broadly, like the diatonic color of its ground note. The wave-time ratios are identical in the three major common chords. Their harmonic characters are therefore exactly alike. But there are differences in the ratios to the key note. These ratios are as follows. (See the table on page 146.)

Tonic chord (and key)	1: 1: 4/5 : 2/3	or	15 : 15: 12: 10
Subdominant chord	1: 3/4: 3/5 : 1/2		20 : 15: 12: 10
Dominant chord	1: 2/3: 8/15: 4/9		22½: 15: 12: 10

The order of simplicity of the ratio to the key note is the order of strength of the chord color.

The elements of music are three, namely,

1. Rhythm, including time and accent,
2. Melody, the succession of notes.
3. Harmony, including tone quality in general.

Of these elements rhythm is the most fundamental and was without doubt the first to be developed. It is still the most important element in popular music. The moving power of a brass band depends on the drum as much as on any other instrument.

Melody, though it comes second in the order of importance and in the order of development, has been the last to be scientifically analyzed. Tone color is the key to its mysteries.

Harmony was practically unknown before the year 1000 A.D., and most of its development has occurred during the last 300 years. Its principles depend upon the mathematical ratios of wave-times, and are well understood.

A fourth element, suggestion, belongs rather to the listener than to the music, for its effects depend upon former experiences of the listener.

Suggestion acts (*a*) by imitation, as when the rippling of water is represented on a piano, or the cry of a child on a violin; (*b*) by natural association, as when lightning is suggested by an imitation of thunder; or (*c*) by individual association, as when some experience of joy or sorrow is recalled on hearing some associated music.

The best and strongest music combines all these elements to produce the desired effects. A clear understanding of the part played by each element in musical composition will lead to a marked improvement in the music produced.

MILTON'S IDEAS OF SCIENCE AS SHOWN IN "PARADISE LOST"

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EGGLESTON'S "Transit of Civilization" starts with an interesting discussion of popular belief in Europe in the seventeenth century. In its literature we find much about astronomy and astrology; especially did they touch the popular imagination. Astronomy must have been a jumble of the Ptolemaic "firm-set earth" and the Copernician theory of the revolution of the spheres. Lowell speaks of Copernicanism as "the theory that has so stirred all our modern wits." It seemed to the suspicious thought of the time to smack of witchcraft; Galileo was imprisoned, Kepler was working in obscurity, and, as we read, occasionally casting horoscopes for princes. "In the best society, the sun, moon and stars continued to revolve around the earth" without gravity and with prognostics dire of diseases and divers fortunes. Astrology was a serious avocation. Comets, eclipses, and meteors were danger signals. "God governed this one little world, and logic was the only means of discovering truth." Finally the Copernican theory evolved constant proof of the correct standpoint; even the making of clocks received an impetus, and "almanacs gradually became filled with those minute calculations with which the world has since grown familiar."

At what point in this evolution of science Milton stood is indicated by the "Paradise Lost." It is probable that he was partly convinced of the truth of Copernicus's system; at least in two striking passages he shows his acquaintance with it.

One (Book IV., ll. 592–597) reveals the uncertain state of his opinion on the subject, where he states that the sun's setting in the west would be more easily explained if the earth revolved eastward. However, to be consistent with the general scheme of the poem Milton must make his "Prime Orb" roll incredibly fast to the west. Again (Book VIII., ll. 15–178), during Raphael's delightfully informal visit to the hospitable lovers, Adam discusses at length with the Archangel this debatable question of astronomy, the outcome of which discussion is later diluted for the understanding of submissive Eve. Adam perceives how difficult it is to believe that the stupendous Universe revolves in one day about "this Earth, a spot . . . that better might with far less compass move." The Angel, however, is not only "affable" but discreet, as he responds that the truth is concealed by God from man and angels, and that speculations (evidently looking far down the ages) "move His laughter." As far as man's duty is concerned it is of no real consequence as to which moves. One feels here that Raphael (and Milton) inclined to the superior simplicity of the Copernican system, in spite of prudent conservatism.

The Ptolemaic theory was evidently more adapted to concentrating the emphasis of the poem on our little earth and its tragedy, whatever Milton's own scientific conclusions may have been. His was a profound mind; he had met Galileo and refers to him in Book I., l. 288, in Book III., ll. 588–590, and Book V., ll. 261 ff.; in his day the struggle between the two theories was waging; it is possible the poet was of one mind, the compact reasoner of another. His scheme in "Paradise Lost" is undoubtedly Ptolemaic. If one dare be expository in the presence of start dust and planetary whirls and the music of the spheres, the plan of the poem may be indicated somewhat thus:

Before time was, space, strangely enough, was in two divisions, the upper half Heaven, the lower Chaos—an inexpressible quagmire. At one day, however, in the annals of timeliness, a place was prepared for the outcast angels, below Chaos. We have now three divisions of "Universal Space." It was a nine-days' fall, or rather retrogression from Heaven, as angels are not subject to gravitation and had to be beaten through Space by Christ's thunders. That Space was as far as from the center of the earth "thrice to the utmost pole of the Universe" (Book VI., 1871); such is the effort of the human mind to express infinite ideas, for which there is no material language. During an ensuing nine days, while the rebel host lay overwhelmed upon the fiery lake in "restless ecstasy" of woe, Infinity is again modified (Book I., ll. 50–53). The new universe is created. Taking a pair of immeasurable compasses, "the Son" fixes their one foot far out in Chaos, and with the other describes a great circle in the void—the boundary of the new creation. Imagination rocks at the image! (Book VII., ll. 224–231). The new universe is attached to Heaven at its north pole, and at the place where an opening is left in Heaven for angelic communication. Who but a Milton would dare be thus exact in the face of infinity! Now for the Ptolemaic theory:

In this sphere the earth is the fixed center, hanging "self-balanced." Nearest earth were the seven planets including the sun and moon, Venus, and the "other wandering fires"—Mercury, Mars, Jupiter and Saturn. (These spheres according to Pythagoras and the most beautiful conception of poetic minds, moved "not without song," "each quiring to the young-eyed cherubim." Cf. also "Ode on the Nativity," stanza XII.)

Beyond the planets was the firmament, an eighth sphere, containing the "fixed stars." This was the sphere that turned from east to west in twenty-four hours, carrying with it "all the planets in their turn," which, however, had all separate motions of their own. There was also a ninth sphere, and finally a tenth, which was called the "Primum Mobile," an impenetrable shell separating the Universe from the turmoil of Chaos. In Book III., ll. 481–483, the ten spheres are enumerated, where the ambitious spirits attempt to ascend from Earth to Heaven, and are whirled aloft to the "Paradise of Fools" on the *outside* of the Primum Mobile.

This, in general, is the scheme that Milton has elaborated in his epic, first in the passage (Book II., ll. 561–565) where Satan, wandering on the dark outside shell of the universe, is attracted to the opening at the zenith, and through that beholds the whole interior; and again in the account of the creation in the magnificent Seventh Book.

The portion marked out by the golden compass from Chaos is impregnated with warmth and light and life by the Word of God. Noxious elements escape into Chaos from the lower part of the sphere. Then follows the "conglobing of like things to like" out of the "four grosser elements"—earth, air, fire, and water, as the ancient Greek philosophers considered them. Light, the fifth element, is evoked by the Creator. The sun, which Satan saw as the most splendid body in the universe, though but the fourth sphere, Milton describes as containing a large part of the light of the world, the Almighty having concentrated it there at the fiat, "Let there be light." (Book VII., ll. 359 ff.)

Milton's interpretation of the "firmament" is the reconciliation of the first chapter of Genesis with the Ptolemaic theory. The firmament separates the waters flowing around the Earth from water "diffused throughout the Universe." This He removed to the outside of the Eighth Sphere, forming the Ninth, or "Crystalline Sphere" separated from Chaos only by the Primum Mobile (Book III., ll. 444 ff.). Thus the firmament was the great extent of space between the earth and the utmost boundaries of the eighth or visible sphere. This vast expanse was named heaven, after the greater Heaven, the abode of God. Line 176 in Book VII. ("Immediate are the acts of God") would seem to imply that Milton conceived of Creation as instantaneous, though perhaps for the sake of human limitations it is described as the work of six days.

Again in Book VIII., ll. 81 ff., occurs a very definite statement of the growth of the Ptolemaic universe by the addition of "orb after orb." Further on the poet refers to the two devices of the eccentric and the epicycle, by means of which complicated system of reasoning the Ptolemaic astronomers tried to explain why the sun's motion seems faster or slower according to the season (Book VII., ll. 82–84), in which connection it is interesting to note that Bacon himself showed his dissatisfaction with such reasoning in De Augmentis, IV., ll. 347–348, where he compares the contribution of astronomy to the human intellect to the fraud practised by Prometheus upon Jupiter.

We find Milton again wavering in Book VIII., ll. 130 ff., where the earth is said to have three motions; rotation on her axis, movement around the sun, and her "trepidation" (Book III., l. 483) during her orbit. Here is the Copernican theory; but in ll. 131 ff. Milton says, "which else" you must ascribe to the old theory that several spheres move contrary to one another with "thwart obliquities." As for the moon, it was supposed to have rain ("Her spots thou seest as clouds"), and perhaps inhabitants (Book III., ll. 145–147). "Other Suns, perhaps with their attendant moons," may be a reference to Galileo's discovery of the satellites of Jupiter and Saturn (*ib.*, ll. 148–149). It is interesting to note at the close of this passage on Milton's uncertain astronomical faith, how opposed are his to Bacon's pronouncements. Milton discourages the inductive process, "nor with perplexing thoughts to interrupt the sweet of life" (Book VIII., ll. 183–197). This is, of course, directly the opposite of all Bacon's teaching as to inquiry into the secrets of Nature with a view to solving her perplexities.

Finally in Book X. is an ingenious explanation, whether Ptolemaic or poetical, of the obliquity of the earth's axis to the ecliptic (ll. 671 ff.). "Some say" that after the Fall, God bade the angels turn the pole so that it no longer pointed toward Heaven's gate. Or else "the Sun was bid" to turn out of "the equinoctial road." At all events, Spring was thus prevented from "perpetual smile" on earth, and days and nights were made unequal.

Milton's astronomy has, I fear, been rather vaguely indicated. It is, indeed, an unexampled combination of vagueness and exactitude, of material limitations and sublimity. It is less of earth than of Heaven and Hell and "Chaos and old Night." It is the conception of a soaring intellect and a blind man who sees flashing lights and geometrical shapes in the darkness.

As to his ideas of natural science, there is less to say. He held, like all his contemporaries, beliefs as to the physical influence of stars on beings of this earth. ("Their stellar virtue," etc., Book IV., l. 671.) "The sweet influences of the Pleiades" were supposed to bring gentle blessings when they were in the ascendant. In the autumn Orion brought storms "with fierce winds armed." "Comets shake pestilence and war" (Book II., l. 710). Astrology, I fancy, was a natural outgrowth of Ptolemaic astronomy. The most striking reference to astrology is in Book X., ll. 658 ff., where the "aspects" of planets is mentioned, which according to tradition were "happy and unhappy" as regards the destiny of man.

Quaint notions of chemistry occur. In Book I., ll. 673–674, Milton expresses the popular belief of the time as to the importance of sulphur. "In his womb was hid metallic ore, the work of sulphur." From Pliny to Bacon, men held that sulphur, mercury, and salt were the all-pervading substances in nature. Other minerals occur; "Naphtha an asphaltus" light the roof of Hell. Alchemy is also referred to in Book III., l. 601, and the "philosopher's stone." "They do bind volatile Hermes" evidently means the solidifying of fluid mercury.

All things need food, even angels and perfect men, "who fell upon their viands"; even elements, of which "the grosser feeds the purer"—Earth the sea, and Earth and Sea the air—they all need nutriment. The moon is fed by mud of the earth sucked up with the moisture, according to Pliny, who is here echoed by Milton: "The moon whence in her visage round, those spots, unpurged vapours," etc. "The sun receives his alimental recompense in humid exhalations, and at even, sups with the Ocean," a statement of which Landor strongly disapproved poetically. Another belief, expressed in Book X., ll. 243 ff., assumes that things "of like kind" have peculiar physical sympathy at whatever distances from each other they be—a sort of atomic telepathy. In Book X., l. 666, we find the old belief that thunder is rolled by winds.

In Milton's natural history, we are again reminded of Pliny, as where serpents "with snaky folds and added wings" are created (Book VII., l. 483). In Book IX., ll. 581–582 is an allusion to the supposed habits of serpents that loved the smell of fennel and were said to suck ewes' udders. "The female bee," according to the belief of the day, is represented as the worker of the hive. The animals in "Paradise Lost" are all highly entertaining. Milton seems to have thought that brutes have a higher degree of intelligence than is usually attributed to them. "They reason not contemptibly," he writes in Book VIII., ll. 373–374. He alludes to the flight of cranes "with mutual wing easing their flight"—each helping the progress of the whole body by becoming in turn the point of the V. The will-o'-the-wisp he calls "a wandering fire" (Book IX., ll. 634 ff.). In accounting for this phenomenon Milton seems very modern, if we take its origin from "unctuous vapor" to mean gas from decaying swampy matter. Vultures are made to "scent a field unfought," as Beaumont and Fletcher also held in "The Beggar's Bush." This must have been a popular superstition. The different kinds of asps, scorpions, etc., in Book X., l. 524, seem to be taken direct from Pliny after the manner of natural historians of the day. Echoes are found here also of Lucan's "Pharsalia" (Book IX., l. 700).

The medical theories of Milton's day occur in various parts of "Paradise Lost," notably in that poignant passage of Book VII. on his own blindness, where he describes it as probably arising from "the drop serene" that left his eyes without blemish; yet he is not sure but that his case is one of "dim suffusion." Eye diseases were thought to arise from affections of "the humours." "Euphrasy and rue (Book XI., 1414) are mentioned as strengthening the eyes; euphrasy was called "eye-bright." The poet had possibly tried both in vain. In Book XI., ll. 477–493, occurs the famous enumeration of diseases—one sad result of Adam's fall. "Moon-struck madness" echoes another popular superstition. "In thy blood will reign a melancholy damp" is a reminder of Burton, who calls old-age "cold and dry" and of the "same quality as Melancholy." "Humours" and their baneful operations were prolific subjects for speculation in the sixteenth and seventeenth centuries, it appears.

Botany in "Paradise Lost" is interesting. What minute and loving memories of plants! Eve's troublesome vines make one think of the charming gardens described by Harrison and Sir Thomas Browne. But to one reader, at least, the most interesting observation, aside from Milton's amazing astronomy, is the detailed and accurate knowledge of geography displayed by the blind man. How minutely he remembered his maps! What marvelous surveys of geographical discoveries! What delight in sounding names! The passages are too well known to need comment. One of the most remarkable, however, is in Book XI., ll. 385–411, where the eyes of the poet's mind glanced over all of the then known Asia, Africa, and Europe—a stupendous feat of memory, as well as an example of "the poetry of proper names." One is reminded of Macaulay's famous passage in his essay on Milton in which he describes the "long muster-roll" of "charmed names."

A striking impression that remains after a careful reading of "Paradise Lost" is the daring use Milton made of his immense knowledge—the combination of definiteness and mystery; titanic pagan angels fighting like the heroes on the plains of Thessaly, but in a definite Ptolemaic scheme; deathless beings, not subject to gravitation; Time in Heaven ("'Two days as we compute the days of Heaven' said the Almighty Father"); Satan suffering from the loss of his immortal ichor, as Mars did at the onslaught of Minerva, and modern methods of blood-stoppage applied; all of gorgeousness, awe, dignity, in a materialistic heaven with fighting angels who dig for metals to make cannon! How could any one at that time have accomplished such audacity with what are called Christian conceptions? Homer is audacious and sublime, but we call him frankly pagan. Again, in portions where exactitude of information is most evident, as in the "muster-roll of names," and in the Ptolemaic astronomy, occur some of the most transcendent passages of poetry!

The seventeenth century writers, it would seem, had an attitude of high romance toward science; at least they wrote about it poetically. (Wordsworth once said it must eventually become a subject for poetry.) Surely we find that poetic sweep of thought in Bacon with his visions of experimentation; in Burton who made a medical treatise read like a novel; in Sir Thomas Browne, whose observations on obscure researches sound like the Book of Revelation; and in John Milton, who marshaled all the hosts of his mighty mind to evolve a vision of creation out of darkness.

SCIENCE AND SOCIAL UNREST

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THIS is the era of science. Were we unable to discover this fact for ourselves we at least would come to believe it from the constant and proud affirmations of the scientist. We are told that science has recreated the world and within a brief century. The facts are so apparent that the person least interested in science has to admit them. At every point human experience has been changed by the contribution of science and invention. Traditions have been broken. Customs have been destroyed and are being destroyed. Social habits have been modified. New motives have followed from the new conditions created by science; former motives have grown faint and are passing. Already science has accomplished beyond the dreams of human fancies of an earlier period. And the end is not yet. Indeed, science never promised more than now and was never advancing with more rapidity.

There is another fact that stands out as clearly these days as that of scientific progress. We are living in an age socially as discontended and feverishly restless as the world has known. The discontent is not, however, a hidden dissatisfaction, far under the surface and known only by the few gifted in genius for penetrating into contemporary conditions. Our social discontent is self-conscious, boastful and even blatant. It is also omnipresent and from it we can not escape. It has entered into the remote countryside and brought under its spell even the least sensitive of farm "help." It has captured the house servant and brought chaos to individualistic housekeeping and our crowded hotels to the point of bursting. Contrary to the opinion of some, it is not class movement, for it cuts across classes and is found among the wealthy just as it is among the poor. It is not in any sense national, for it appears to have swept the entire temperate zone like a rapid-moving pestilence.

If the scientist has made our era, he surely must also accept responsibility for our characteristic unrest. It may be that the world has indeed been recreated, but it has not yet been brought to a condition of safety. The scientist in the past has given scant consideration to the social problems created by his splendid success in mechanical and industrial development. Human nature, as the war has taught us, has changed little since the time of primitive man, and during the last century with the wonderful advancement of science there has not been equal progress in human discipline or intelligence. The things that men handle have been multiplied and magnified, while man himself has lagged behind, altogether too confident that the results of material progress would in themselves bring social satisfaction and sanity.

It was a foolish assumption. To hold it now is stupid stubbornness of mind. There are some who by heroic effort still cling to it, fearing that nothing else can give a substantial basis for the idea of progress. It is, however, growing more and more difficult for any one to believe that social security will necessarily follow from the contributions science is making that enrich the material resources. The unpalatable but enormously significant fact can only be held out of consciousness by the persons who are willing to cloud the social truths if for a season they may protect their intellectual comfort from such disquieting disenchantment as would follow the admission that unrest has become the dominant social phenomenon in this age of scientific prosperity. It is becoming increasingly difficult, however, for any one to shut his eyes to the premonitory fact that stands out so clearly. A multitude of men and women are by no means socially content in this era of science; they are profoundly dissatisfied and their souls are seething with restlessness. The solid fact can not be pushed aside by refusal to recognize it.

From a social point of view science has not been as successful as the average scientist imagines. Science means more than a mere collecting of information. It is not simply a classifying in a systematic way of all the trustworthy facts known at the time. It is especially an attitude of mind and one that human nature acquires with painful difficulty. It originates, to be sure, from a universal instinct of curiosity, but the finished product contains an element of personal indifference which is foreign to the unmodified instinct. Science is the highest form of that reality thinking of which the psychoanalysts make so much and stands in sharpest contrast with their definition of the easygoing pleasure-form of thought. It is the most heroic effort the human mind can make to get rid of all personal inclination and bias in meeting an intellectual problem in order that the truth of any matter may be as accurately known as is possible. It is in its success in putting aside personal desire that scientific thinking distinguishes itself and wins the right of intellectual supremacy. Huxley has most happily expressed this spirit of self-renunciation on the part of the scientist when he faces any investigation.

> Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of active surrender to the will of God. Sit down before fact as a little child, be prepared to give up any preconceived notion, follow humbly wherein and to whatever abysses nature leads or you shall learn nothing.

Unscientific thinking is under no such coercive discipline, but may, if it pleases, follow hard after personal desire even though at the end one be ditched from having neglected fact for fancy.

Science has, by its superior attitude of mind, accomplished marvels and obtained a spectacular success. It has not, however, given the great mass of people any appreciation of its highest function. Science has been valued by the majority of people for its accomplishments, not for its portrayal of the advantages of stern discipline in mental experience. It has merely encouraged a vast multitude to believe that human existence is a never-ending pleasure hunt and science the best giver of material comforts and luxuries. The craving for personal gratification has been stimulated by the magic-like productions of science until an appetite has been created that nothing can satisfy. Social well-being has needed the teaching of science more than its products. The philosophy of the street admires science for its liberality in things; it turns with indifference from any attempt to popularize the self-restraining spirit of science. The scientist is welcomed as a good workman; he is ignored as a teacher.

From such a situation social sanity can not be expected. Science increases the power and freedom of men; it fails, or thus far has failed, to prepare them for the proper use of their increasing opportunities. The race with its hundred thousand years or more of stern discipline and struggle is hardly ready for the present enormous quantity of pleasures and the life-motives that are constructed in pleasure-terms. The social problem has come to be merely making life easier for a greater number of people and by some process permitting material pleasures to be equally shared.

Even if we assume that this program states the goal of all social endeavor it by no means follows that its working out is a simple matter. The problem of method still remains and here, if ever, there is need of patient scientific investigation and experimentation. Social experience ought by this time to have taught men how complicated the details of any such program must be and how foolish it is to attempt a quick and à priori solution. Why is it one may well ask that the popular thought is so intolerant of giving to science the problem of finding a more just distribution of material wealth? The world-wide drift of population toward the cities is part explanation of the confident social philosophy that can not endure the thought of giving even so delicate and hazardous a problem over to "cold-minded" science. Urban life does not tend to teach men caution in the working out of social programs, for it is difficult in the city to have that first-hand contact with nature, which, more than any other human experience, provides the basis for moral discipline and curbs the arrogant and unreasonable demands of men and women. The city, by hiding the natural obstacles that always hamper the accomplishment of man's purposes and by turning the attention to the competition one person has with another, encourages the belief that the difficulty of obtaining one's complete happiness is due to the interferences of other people. The constant experiences of rural people with the menace of frosts, blights, insect pests and droughts impress upon them the elemental fact that nature itself is often in opposition to the purposes of men. Rural philosophy becomes by instinct suspicious of any get-right-quick social scheme.

City conditions provide the perfect opportunity for the gregarious leader, who wins his power by skill in directing urban discontent and industrial restlessness. He is by temperament unsympathetic toward the cautious experimental methods of science. Indeed he could not hold his following by a judicial attitude toward social grievances, for they follow him not for his accomplishments, but for his ability to voice in catching phrases their inarticulate discontent. Everything in the city conspires to turn this dissatisfaction into economic form. The conflict of classes, the apparent omnipotence of money to furnish the conditions of health, social standing and happiness to the well-to-do of the city and to deny them to the poor, the constant pressure of economic competition, these influences and many others of similar character all tend to magnify the value of money and to conceal the ever-present checks upon human purposes that nature will present under any form of social régime. The urban problem of life boils down to the getting of sufficient money to satisfy one's desires and it becomes the conviction of a multitude that their satisfactions can be increased only by placing limitations upon other people whose desires collide with their own.

Since the modern city is the creation of science, science must assume responsibility for the intense gregarious appeal that it is now making throughout the civilized world. No person, however great his indifference toward science, ever visits our greatest city without appreciating how science makes possible modern New York. The very existence of the city is conditioned by the inventions that face the visitor on every hand. Were any of the more important contributions science has made to the city's welfare to be removed or made inactive, in an hour's time the city would change from a place of business and amusement to a horrible death trap from which men, women and children would flee as from the clutches of a devouring monster.

It is folly to regard our present social crisis as merely a succession of disputes regarding wages, commodity prices and hours of labor. It is not merely based upon dissatisfaction with our present capitalistic system. In the present temper of the people no change, whether it be in industrial organization or wealth distribution, can bring cessation of social restlessness. Science has created an appetite that no governmental or industrial regime can satisfy.

The situation in which the world finds itself, which the war has hastened but not caused, resolves itself in its lowest terms to the impossibility of a people socially unscientific living a satisfactory life in a scientific era. The safe way out, the path that is likely to be chosen after painful social experiences in any case, sooner or later, is through the popularizing of the spirit of science. The task is not impossible, for any social attitude can be taught by a vigorous, determined leadership.

For the most part in the past science has been indifferent to its teaching function. Many of its leaders have been aristocratic in their conception of science and have looked askance at their colleagues who have had a mild desire to bring to the average person a taste of the sweet fruits of the scientific mind. Especially has the scientist cared little whether science was taught in the public schools or whether it was so taught as to give the developing pupil a glimmering of the methods by which science wins its conquests. College teachers of science have not infrequently dismissed the problem of high-school science with the comment that they always have found that pupils who have had no science in the high school are the best prepared for college courses in science, refusing to accept the testimony of the students respecting the value of their preparatory courses. The vocabulary of the scientist and his manner of writing and speaking has in general been unnecessarily esoteric and he has been proud of the self-imposed limitation that has given him a class consciousness.

On the other hand, the scientist has been subservient to the ambition of commerce and never-ending effort has been made to popularize the demands for the products of science. By means of human ingenuity, by advertising propaganda of tremendous economic cost, the appetite for things has been stimulated and the concept built up that the happiness of man does consist in the abundance of the things he possesses.

Society desperately needs a democratic science. In very recent years, especially in medicine, there has been a most encouraging movement toward the socializing of science and the acceptance on the part of the scientist of his obligation as a public teacher. Medical science deserves the greatest appreciation for this splendid service carried on often against the self-interests of the profession. It is, however, not the results of science that the people need so much as its spirit of rational discipline.

The promise of social progress is in science teaching men and women with the same success that now it feeds, houses and gives them playthings.

POPULAR MISCONCEPTIONS CONCERNING NATURAL HISTORY

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THERE is in the popular mind a surprisingly large store of misinformation and misconceptions concerning many forms of natural history. They concern not only exotic and the less well-known plants and animals, but our commonest forms share prominently in these misbeliefs in spite of the large amount of published information on natural history and opportunities for individual observation. To err is human and all classes share to a greater or lesser extent in errors of judgment and observation. But there is a large class of traditional errors that have become more or less fixed, some locally, others nationally. It is this class, a part of our folk lore, which has been perpetuated in many cases in books, magazines, newspapers and traditions with which this article will deal. It is perhaps impossible to find the origin and to trace the development of our common natural history misconceptions. It is possible by an analysis of some of our most widely known ones to assign probable explanations of their origin and by the application of certain well-known principles of human psychology to understand their perpetuation.

It should be mentioned first that the perpetuation of our traditional natural history misconceptions is made possible largely by the fact that a considerable portion of the people do little or no reading. There is also a class which reads for thrills and not for information, that may be included with the above. There is in print enough accurate information to set at naught most or perhaps all of what is commonly termed popular misconceptions. It appears that prevalence of natural-history superstitions and misinformation in countries and communities is in inverse ratio to the amount of reading done. It is perhaps true that the country people perpetuate more of this misinformation than do city people, though the difference is not so great as is generally thought.

It has been frequently stated that human nature is inherently lazy. One apparent manifestation of this is that many individuals prefer to take another's explanation of some phenomenon rather than to secure the information for themselves. This is of course not a characteristic of the untutored mind alone, but college students very commonly follow this line of least resistance. This fact makes possible the perpetuation of gross inaccuracies. It is commonly stated that the earthworms seen so often crawling about after a hard rain have fallen with the rain. An observation requiring only a few minutes would reveal the holes in the water-soaked earth through which they have emerged and perhaps a few in the act of emerging.

The statements of the more prominent people in the community are more likely to go unchallenged than those from the less well known. This prevails among all classes. A very prominent early worker in entomology figured grasshoppers laying eggs in an impossible position fifty years ago. This figure has been widely copied and accepted without question until a few years ago, when it was disproven. It would have been an easy matter to check up this observation had not the prominence of the early worker given added confidence to the earlier conclusions. There are no doubt, many errors in scientific writings perpetuated because of the prominence of the writer, whereas the unknown scientist might be quickly doubted.

An acceptance of the opinions of others is most frequent when individual observations are difficult or impossible. The group of misconceptions arising in this connection is naturally a large one, since superstition, hearsay and exaggeration play important parts. It is impossible for the rank and file to follow the latest scientific discoveries explaining even most familiar phenomena, much less to investigate for themselves. Consider the following in this connection. It is quite generally believed that flies are able to walk upside down because they have suckers on their feet. This is an old idea which has persisted, largely in the popular mind, though it has long been known that there is a secretion of adhesive material from minute glands on each tarsal pad which enables the insect to literally glue itself to its sub-stratum. Again, animate objects that glow or glisten are generally said to possess phosphorescence. The best known instance is that of the lightning bugs or fire flies which are often seen by the thousands on a warm summer's evening. Recent studies apparently find no basis for this belief, but explain the light as due to rapid oxidation of certain cell substances. Less frequent perhaps is the belief that the glistening of the cat's eyes in the dark is due also to phosphorescence, when the true explanation is said to be the reflection of entering light by the tapetum, a thin membrane covering the retina. Quite general is the belief that mad dogs foam at the mouth; in fact this is thought to be the one thing to look for when a mad dog is suspected. Published observations indicate that foaming at the mouth is not present in all cases and when present is not the first manifestation of hydrophobia. The streaks of light so often seen in summer in the west below the sun is explained as the sun drawing water. At times, it is commonly thought the sun draws with such force that the earthworms, frogs, snakes and even fish are drawn up to be dropped with the next shower.

Perhaps the majority of misconceptions concerning natural history are based on mistaken observations and misinterpretation of the facts involved. Many people arrive at conclusions quickly and an explanation that appears plausible to one is likely to appeal to others. Such misconceptions arise from new sources constantly. A beaver's tail, for example, suggests a trowel, especially when considered in connection with its houses. It is not surprising that there has arisen a persistent misconception sometimes seen in school texts that the beaver's tail is used as a trowel. Seton finds no evidence whatsoever to substantiate this belief. Its front legs and chin are its chief tools in building operations, while the tail serves chiefly as a propelling and guiding force while swimming and to "slap" the water as a signal to its associates. The beaver is said to drive stakes or piles in the mud of streams, another fallacy based on a superficial observation of the sticks and not a study of the animal. The porcupine is said to shoot its quills at its enemies because possibly of the superficial resemblance of the quills to arrows. Indeed, when a dog attacks a porcupine he invariably comes off with some quills in his flesh, which is accepted as further proof that they were shot like arrows at him. It is of course impossible for this animal to protect himself in this manner, there being no muscular or other arrangement to effect it. The quills are very loosely attached, therefore easily dislodged. They are also very sharp and readily puncture the flesh of its captor.

Some misconceptions of this class have been given prominence and perpetuated by incorporating them in the common names of the animals themselves. Flying squirrels and flying fish are familiar subjects of natural history, yet neither actually fly. The so-called flying squirrels are gliders or parachuting animals only, inasmuch as they can only descend from a higher place to a lower, using the extended skin between the fore and hind legs in the same way as a parachute is used. The so-called flying fish appear superficially to be true flying animals for the enlarged pectoral fins suggest the wings of a bird. Yet there is no doubt that they use these fins as planes for gliding only. The propelling force is the tail which supplies the momentum before the fish leaves the water. The longest glides are made against the wind. There is no suitable musculature to effect a flapping movement. There are many available illustrations among insects where the common names involve an error of some kind. Popularly speaking, all insects are bugs when, strictly speaking, this name applies only to one order of sucking insects (Hemiptera). The larvæ of some insects are called worms when this name is more properly applied to members of the *phylum annulata,* of which the earth worm is a type. Clothing, carpets, etc., are said to be attacked by the clothes moths, yet in no case is the injury done by the moths, but by the larvæ of the moths, the former feeding on nectar or pollen and being quite harmless. The buffalo bug is not a bug but a beetle; the pear slug is not a slug, but a slug-like larva of a true insect; the sheep tick is not a tick, but a fly, etc.

It appears further that of all animals, there are more misconceptions concerning the ugly and disliked ones than others. The skunk, weasel, toad, snakes and spiders are not general favorites with the people at large; in fact they are shunned and even a distant acquaintance is abhorred. The less known about an animal, the more readily will hearsay, mistaken ideas and imaginative tales be believed. Snakes are perhaps the most widely feared and despised of all creatures. It is not surprising, therefore, that we have such fantastic stories as the hoop snake, the glass snake, the monster sea serpents, mother snakes swallowing their young in the presence of danger, not to mention the mythical scaly monsters that exhaled smoke and fire. The snake charmer makes a living by taking advantage of the lack of true information about these much abhorred creatures as well as of various superstitions and misconceptions concerning them. No circus would be complete without its dangerous snake, the largest in captivity. It is quite generally believed that all snakes and spiders are poisonous and their bites would prove fatal, when authentic accounts say there are many of both that are wholly harmless. Snakes are said to be deaf, and only last year this misconception appeared in prominent head lines on a page about snakes in a leading Sunday paper. True, there is no external ear present, but there is nevertheless a pair of ears and the old adage "as deaf as an adder" is no longer expressive. Rattlesnakes are supposed always to rattle before striking, a kind of gentlemanly sportsmanship to warn the victim that he still has a chance. Observations recorded appear to show that the rattlesnake may forget this chivalrous act and strike without warning. The writer believed throughout youth that when a snake was killed, its tail would not die until sun down. This misconception has been met with among youths of three widely separated localities. The brain of snakes is small, consequently some powers held by the brain in certain other animals are delegated to the spinal ganglia in the snake, therefore crushing or severing the head of the snake does not remove the possibility of body movements from impulses emanating from these ganglia. Perhaps some one disliking cats started the revolting story that if a cat was left alone with an infant, it would kill the child by sucking its breath. This impossible thing is quite generally believed, though without basis of facts.

Then there is another prominent group of misconceptions bearing little semblance of truth whose origin is perhaps the work of a fertile imagination. Consider, for example, the well-known belief that a horse hair will turn to a snake. It must be a hair pulled out by the roots from either the mane or tail and kept in quiet water, we are told, and in due time it will be a snake. Thus *Gordius* and other closely related round worms which are about the same size as horse hairs are supposed to come into existence. Of course no one has even been able to effect this transformation, because he failed to follow directions carefully. The earwigs (Forficulidæ), relatively common insects in Europe, are so named because they are supposed to puncture people's ears. This reminds us somewhat of the very general belief in the United States that dragon flies sew up the ears of bad boys with their long abdomens which superficially suggest a stout needle. But one of the best examples of this class is the well-known supposed performance of the "doodle bugs," more properly known as ant lion larvæ (Myrmeleonidæ). These larvæ make little pits in sandy places and wait concealed, except for the protruding jaws at the bottom of the pit, for ants. The story goes that when a pit is found, if one repeats the following couplet, the hidden larva will immediately leave its pit and pass in review before the observer. One version is, "doodle bug, doodle bug, fly away home; your house is on fire your children will burn." There are various modifications of this charm in different localities. This is one of very few instances where a lowly insect is credited with "knowing" its name.

There is a difference in the misconceptions about objects of natural history in different localities thus introducing some interesting variations. The writer had this forcibly brought out in several communities by the various popular rules to follow for determining which mushrooms were edible and which were poisonous. In one community, those that were pink underneath were regarded as edible by some collectors, in another community these were discarded as poisonous. The same divergence of opinion was observed with the rule that if they would peel they were edible and with those growing on wood. In one community to find water with a forked stick, a peach twig had to be used, elsewhere cherry or willow was always used. One finds a host of examples of local differences in superstitions. In some homes the chirp of a cricket in the house is regarded as a "good sign," in others fortelling disaster. Likewise the screech owl in some communities is supposed to foretell by its plaintive song evil happenings, at other places, announcing good news. In some communities killing a toad will cause all the cows in the neighborhood to give bloody milk, elsewhere robbing a robin's nest will effect the same result according to the superstitious folk. The crowing of the cock before midnight is in some places the herald of rain the next day, elsewhere it merely announces a visitor.

The chief importance of a consideration of these and other misconceptions of natural science, excluding the student of folklore, is their effect on the youth. These mistaken ideas become fixed in the minds of children, perhaps when very young, and will persist until corrected. Classes of fifth-grade children in the public schools of Milwaukee invariably stated that the ostrich in the presence of danger buried his head in the sand, and immediately felt safe, on the principle that if he could see no danger there was no danger. Perhaps seventy-five per cent. would uphold this idea. This explanation has persisted with the public generally and can be found in many books at the present time, notwithstanding reliable observers report this to be fallacious. In the writer's community it was almost universally believed that dragon flies were snake doctors whose chief duty it was to heal sick and wounded snakes. This supposed duty was the source of considerable prejudice against these beneficial creatures, and we therefore killed them at every opportunity. Likewise the barn swallow was killed and its nests destroyed whenever possible, for it was supposed to carry bed bugs.

Children are told these things by parents, servants, playmates or neighbors and in rare cases in the elementary schools.

Their confidence in these people causes them to believe them unreservedly. In many homes, especially where little attention has been given to scientific facts, boys and girls gather together a surprisingly large store of mistaken ideas and misconceptions about natural history before reaching school age. This fact is all the more significant when we recall that, for most of us, it requires more effort to correct a mistaken idea than to learn a new one. The daily and Sunday newspapers have a share of the responsibility for some of the misconception in this connection. In their effort to present the unusual and supposed revolutionizing discoveries, the truth is sometimes handled recklessly. Furthermore, purported scientific observations made by correspondents and others are often misleading. Aside from the uselessness and burden of mistaken information, there is an important practical and economic aspect to this subject. The individual may be made to fear or despise a truly beneficial creature and to kill it at every opportunity for reasons based on errors. Which creatures are beneficial to man and which are harmful are, after all, too important considerations to be based on errors.

Let these truths be added arguments for the serious and efficient teaching of nature study in the public schools, for if popular misinformation about well-known objects of natural history is ever corrected, it will be largely through the initiative and intelligent direction of the schools.

THE MECHANISM OF EVOLUTION

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IV. Mendelian Inheritance

THE factors of development, whether of an individual or of a species are both intrinsic and extrinsic, hereditary and environmental; but every evolutionary change must be inherited else it would be ever-changing and evanescent; consequently only inherited changes in organisms are of evolutionary value. The chief problems of evolution concern the manner of origin and fixation of these inherited changes. Nearly thirty years ago Osborn said: "When we have reached an inheritance theory that will explain the facts of heredity the problem of the causes of evolution will be a thing of the past."[1] We have now reached a theory of inheritance that explains the main facts of heredity and both directly and indirectly it has contributed enormously to the solution of the evolution problem. But although certain phases of that problem are now things of the past many new phases have appeared which are still unsolved.

The history of Mendel's discovery and the principles of Mendelian inheritance have been described so frequently of late that it is not necessary to dwell upon them here. In bare outlines the essential features of this theory and of later additions to it may be summarized as follows:

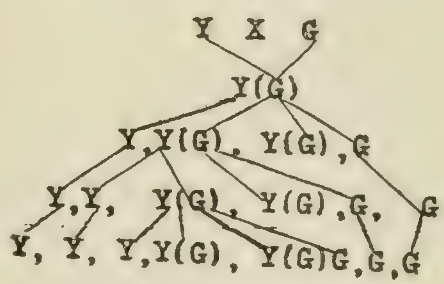
1. Alternative Inheritance

Sexually produced organisms are mosaics of characters each of which is usually derived from one or the other of the two parents but not from both. These alternative characters or their germinal factors are known as allelomorphs. For example, Mendel found that when two varieties of peas are crossed, one having yellow seeds (Y) and the other green (G), all hybrids of the first generation (F_1), had yellow seeds but with green recessive or latent, Y(G), as was shown by the fact that when each of those hybrids was self-fertilized it produced

[1] Osborn, H. F., "Evolution and Heredity," Woods Hole Lectures, 1891.

a second generation (F_2) which formed yellow and green seeds in the proportion of three yellows to one green (3Y:1G). In subsequent generations (F_3, F_4, etc.), if flowers were self-fertilized, green seeds always gave rise to plants with green seeds, one third of the yellow seeds produced plants which bore only yellow seeds, while two thirds of them produced plants which bore yellow and green seeds in the proportion of three to one (3Y:1G) as in the second hybrid generation. The whole result may be summarized in the following scheme:

Parent Generation (P)—
First Filial Generation (F_1)—
Second " " (F_2)—
Third " " (F_3)—
Fourth " " (F_4)—
Etc.



That is green-seeded plants always breed true when self-fertilized, those which are pure yellow-seeded also breed true, while those which are hybrid yellow and green with the green recessive, Y(G), give rise in each generation to yellow-seeded and green-seeded plants in the proportion of 1Y:2Y(G):1G.

Mendel found that the same principle held true of several other contrasting characters or allelomorphs such as round (R) and wrinkled (W) seeds, tall (T) and dwarf (D) stems, etc. In every case he found that the first hybrid generation resembled one parent only with respect to any of these contrasting characters and these characters he called *dominant* while those which became latent or hidden in the hybrid he called *recessive*. In some cases hybrids are more or less intermediate between the parents and in such neither character completely dominates the other; thus Correns found that when

[2] All kinds of germ cells, whether plant or animal, male or female, are known as gametes and the union of male and female gametes gives rise to the zygote, which is the fertilized egg or the organism into which it develops. When two gametes with the same hereditary constitution unite they produce a *homozygote* or pure-bred individual; when gametes of different constitution unite they produce a *heterozygote* or hybrid. All the gametes produced by a homozygote are of the same hereditary type, those produced by a heterozygote are of two different types for each pair of contrasting characters of the parents. The various types of hereditary constitution, such as are indicated by YY, Y(G), GG in this table are known as *genotypes;* the types of developed organisms are *phenotypes.* Thus the three genotypes named constitute only two phenotypes since YY and Y(G) give rise to developed organisms which look alike.

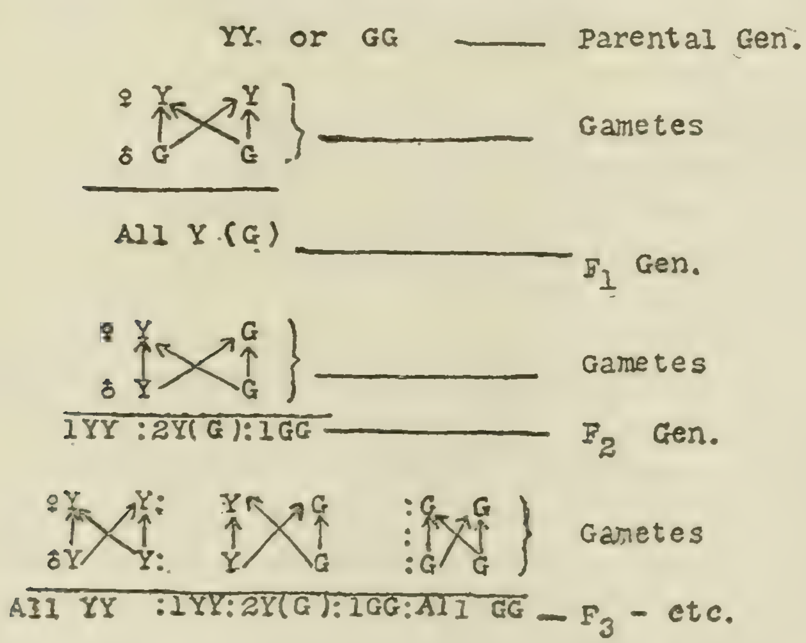
a white-flowered variety of *Mirabilis*, the "four o'clock," was crossed with a red-flowered variety all of the hybrids of the F_1 generation had pink flowers and from these in the F_2 generation there came white-flowered, pink-flowered and red-flowered forms in the proportion of 1 white; 2 pink; 1 red. This is a better illustration of the Mendelian law than is offered by the peas, since in this case the hybrids are always distinguishable from the pure dominants.

When peas with two contrasting characters are crossed only the dominant characters appear in the F_1 generation but in subsequent generations every possible combination of these characters occurs. Thus when peas with yellow and round seeds (YR) are crossed with green and wrinkled (GW) the F_1s are all yellow and round-seeded, but with green and wrinkled recessive, Y(G)R (W), and these, when self-fertilized, yield 9YR : 3YW : 3GR : 1GW in the proportions named.

When peas with three contrasting characters are crossed, one having yellow and round seeds and tall stem, (YRT) with one having green and wrinkled seeds and dwarf stem (GWD) all hybrids of the first generation have yellow and round seeds and tall stem, the other characters being recessive, Y(G)R(W)T(D); but when these hybrids give rise to the second hybrid generation (F_2) all possible combinations of these original characters appear, and in the following proportions:—27RYT : 9RYD : 9RGD : 9WYT : 3RGD : 3WYD : 3WGT : 1WGD. These characters are therefore separable in heredity; they behave as separate units in hereditary transmission and are therefore called "unit characters."

Purity of Germ Cells.—Mendel clearly perceived that there must be things in the germ cells which corresponded to or gave rise to these characters in the developed plant and, although he represented these things by letters, he did not attempt to define or describe them. It was evident that these things or factors or *genes* as they are now called were separable in heredity and that every germ cell, even though it came from a hybrid, could carry the genes for only one of each of these contrasting characters. Thus the hybrid produced by crossing green with yellow-seeded peas must form equal numbers of two kinds of germ cells, one carrying the gene for green seeds and the other that for yellow. No germ cell could carry both of these genes and this led to the most important of the Mendelian discoveries, namely that in the formation of germ cells there is a separation or segregation of genes so that every germ cell is "pure" with respect to the genes for any two contrasting characters.

Consequently when a germ cell carrying the gene for green (G) is fertilized by another carrying the same kind of gene (G) a pure bred green-seeded plant results (GG); when a germ cell carrying the gene for yellow (Y) is fertilized by another carrying a similar gene (Y) a pure yellow-seeded plant is produced (YY); but when a germ cell carrying the gene for yellow (Y) unites with one carrying the gene for green (G) a hybrid carrying both genes results, Y(G), the yellow gene however being dominant over the green. All the germ cells of a pure green-seeded plant carry the green factor, all those of a pure yellow-seeded plant carry the yellow factor, but half of the germ cells of a hybrid between yellow and green-seeded plants carry the factor for green and the other half the factor for yellow. Consequently since in the last named case these two kinds of germ cells are produced in equal numbers there is one chance in four that two germ cells with the yellow factor will unite or that two with the green factor will unite while there are two chances in four that a germ cell carrying the yellow factor will unite with one carrying the green factor. All this may be summarized in the following scheme:



Monohybrids, Dihybrids, Trihybrids, etc.—When parents differ in only a single pair of contrasting characters, as in yellow or green seeds, round or wrinkled seeds, tall or dwarf stem the resulting offspring are monohybrids; where they differ in two pairs of characters the offspring are dihybrids; where they differ in three pairs they are trihybrids, and where they differ in more than three pairs of characters the offspring are polyhybrids.

When the parents differ in only one pair of contrasting characters or allelomorphs, one of which completely dominates the other in the F_1 hybrids, there are in the F_2 generation 3 genotypes and 2 phenotypes, or developed types, in the relative number of 3 dominants to 1 recessive; this is the simple Mendelian or monohybrid ratio. When the parents differ in two, three or more such characters the number of types and their ratios are the square, cube, etc. of those for the monohybrid, as shown in the following table:

NUMBER OF GENOTYPES AND PHENOTYPES WHEN THERE ARE FROM 1 TO 7 PAIRS OF ALLELOMORPHS

Pairs of Allelomorphs	Number of Genotypes in F_2	Phenotypes in F_2	
		Number	Ratios
1	$(3)^1=3$	$(2)^1=2$	$(3:1)^1 = 3:1$, *i. e.*, 1 phenotype (of 3 individuals): 1 phenotype (of 1 individual)
2	$(3)^2=9$	$(2)^2=4$	$(3:1)^2 = 9:3:3:1$, *i. e.*, 1 phenotype (of 9 individuals): 2 phenotypes (of 3 each): 1 phenotype (of 1 ind.)
3	$(3)^3=27$	$(2)^3=8$	$(3:1)^3 = 27:9:9:9:3:3:3:1$, *i. e.*, 1 (27):3(9):3(3):1(1)
4	$(3)^4=81$	$(2)^4=16$	$(3:1)^4 = 81:27:27:27:27:9:9:9:9:9:9:3:3:3:3:1$, *i. e.*, 1(81):4(27):6(9):4(3):1(1)
5	$(3)^5=243$	$(2)^5=32$	$(3:1)^5 = 1(243):5(81):10(27):10(9):5(3):1(1)$
6	$(3)^6=729$	$(2)^6=64$	$(3:1)^6 = 1(729):6(243):15(81):20(27):15(9):6(3):1(1)$
7	$(3)^7=2187$	$(2)^7=128$	$(3:1)^7 = 1(2187):7(729):21(243):35(81):35(27):21(9)$:-7(3):1(1)

Where there are many allelomorphs the possible number of genotypes and phenotypes, due to different combinations, becomes very great and the relative numbers of the different phenotypes differ widely. In almost every case parents differ in more than a single character and in many cases, such as species crossings, they differ in a great many characters. It would not be possible to determine experimentally the absolute and relative numbers of different types in such cases without an enormous number of offspring. Fortunately it is usually possible to deal with each pair of contrasting characters by itself and without regard to the others so that, in such a case, one determines for each pair of characters whether they occur in the simple Mendelian ratio of 3:1.

Thus not only the different combinations which are possible but also the relative numbers or ratios of these different combinations are all explained by the simple principle of the "purity" of a germ cell with respect to any given gene and the chance union of germ cells in fertilization. *This is undoubtedly one of the greatest discoveries ever made in the field of biology and it is as far-reaching in results as it is simple in principle.*

This principle of the separableness of inheritance factors or genes in hereditary transmission has been demonstrated in hundreds of cases in both plants and animals and there is now no reason to doubt that it is a universal law of heredity. The many apparent exceptions to this law which were noted when the Mendelian discovery was new have been shown to be due to misunderstandings of the principles involved, or to unwarranted emphasis upon certain minor phases of Mendel's theory, or to a failure to properly analyze the characters in question or their causes.

The Factorial Theory of Heredity.—Germinal factors or genes are not wholly independent things though they may be localized in the chromosomes and may be separated, transposed and recombined in sexual reproduction. Furthermore it is not true that genes are merely the developed characters, in minute form, or that the factorial theory merely shifts the mysteries of heredity from the region of visible characters to that of invisible factors. Genes are not undeveloped characters but rather the elements whose combinations and interactions produce developed characters, just as combinations of chemical elements produce chemical compounds or as combinations of cells produce tissues and organs. The properties of the compounds or organs or characters are not to be found as such in the elements or cells or genes which enter into their genesis but they result from the combination or synthesis of these elements. Morgan says that each gene probably influences many characters and that it may possibly influence every character of the developed organism, and on the other hand it is known in certain instances that more than one gene is concerned in the production of a particular character. But while it is true that one gene may influence many characters and that more than one gene may be concerned in the production of a given character it is generally true that a particular gene is the *differential factor* in the production of any particular character. Very many factors are involved in the production of a white or red flower, of a white or black guinea pig, but in each case there is at least one factor which is *differential,* that is it is found in one of these alternatives and not in the other. This differential factor alone is emphasized in dealing with the hereditary causes of these differences,—it is sometimes spoken of as if it were the only factor or gene concerned in the production of the character, whereas all that is meant is that it is the differential factor.

Multiple Factors.—When more than one gene is concerned in the development of a character the factors or genes are said to be multiple. Thus in many instances the development of color is dependent upon two or more separable factors, and only when all of these factors are present does color develop typically. A similar condition is usually found in the inheritance of size, and gradations in size or color may be explained as the result of varying combinations of these multiple factors.

Modifying Factors.—Akin to cases of multiple factors are those conditions in which the action of a principal factor is modified by subordinate factors. Morgan and Bridges have discovered six or seven such factors which modify the "Eosin" eye color of *Drosophila.* These modifying factors are also separable in heredity and the stronger or weaker development of certain characters can be shown to depend upon certain combinations of these modifying factors. The fact that selection may serve to build up or to reduce a character is known to be due in some instances to the selection of individuals with or without certain of these modifying factors.

Lethal Factors.—Finally Morgan and his associates have demonstrated the existence of a considerable number of lethal factors in *Drosophila* which cause the early death of those gametes or zygotes in which such a factor is not balanced by a normal one. Consequently only heterozygotes with respect to such lethal factors survive and all individuals which are homozygous for a lethal factor usually die so early that they are never seen. Nevertheless their existence can be determined by indirect methods, such as linkage with sex. Such lethal factors modify expected Mendelian ratios and greatly complicate the study of genetics, but they do not destroy its fundamental principles, indeed when properly understood they furnish one of the strongest proofs of the truth of the factorial theory of heredity.

The factorial theory is as necessary to the study of heredity as is the atomic theory to the study of chemistry and the one is as well justified by the results obtained as is the other. Weismann says that for a long time he tried to avoid the assumption of the existence of inheritance factors, but he finally came to the conclusion that no understanding of the phenomena of heredity was possible on any other basis. At present inheritance factors are no more hypothetical than are atoms and electrons. We know not only that they exist but also that they are located in the chromosomes; we know how they are separated and recombined in sexual reproduction and we know that evolution is caused in some cases at least by changes in these factors or genes.

2. Blending Inheritance

When the Mendelian theory was new it was generally supposed that there were forms of inheritance which differed materially from the Mendelian type; in fact it was supposed that the latter was one of the less common forms of heredity and that blending of parental traits and not separation was the rule. Among such cases of blending inheritance may be mentioned the color of hybrids of white-flowered and red-flowered "four o'clocks" and of white and black men, the size of hybrids of large and small races of rabbits or other organisms, etc. In these cases the F_1 generation is more or less intermediate between the two parents but the significant fact, which was formerly overlooked, is that in the F_2 and subsequent generations we have a more or less complete segregation of the original characters out of these hybrids in which the characters are blended. In the F_2 generation the pink-flowered "four o'clocks" produce white-flowered and red-flowered as well as pink-flowered plants, the children of mulattoes range in color from white to black, the offspring of those hybrids which are intermediate in size between their parents are large and small and intermediate. In these cases there is a true Mendelian segregation of genes but owing to the fact that one gene does not completely dominate its allelomorph or to the fact that multiple factors are present in varying numbers the hybrid is intermediate between the two parents.

Other cases of apparent blending inheritance are found in quantitative characters in which the size of offspring or the degree or extent of their pigmentation ranges all the way from one parental type to the other. Such cases have been studied particularly by Castle in rabbits and in hooded rats and he concluded that such intergrades could not be explained by the segregation of constant genes but must be attributed to quantitative and qualitative changes in the genes themselves. MacDowell, on the other hand, showed that in rabbits the intergrades in size may be explained more satisfactorily by the multiple-factor hypothesis than by Castle's hypothesis of changes in the genes themselves. And the work of Morgan and his associates on the gradation of eye-color in *Drosophila* has shown that such gradations are due to "modifying factors" which increase or diminish the action of the principal factor.

Castle has more recently accepted this principle of modifying factors as an explanation of the results of his work. There are then in all these cases several factors which are concerned in the production of these quantitative characters and the intergradations which occur are due to varying combinations of these factors rather than to modifications of the factors themselves. Blending inheritance, therefore, so far from being a contradiction of the Mendelian principle of the segregation of unchanging factors, becomes an important argument in favor of that principle.

3. Species Hybrids

a. Numerous Allelomorphs.—In species crosses certain phenomena occur which do not appear to be Mendelian in character. For example, species hybrids are usually intermediate between the two parents so that it looks as if this were a case of blending inheritance. This appearance may be due to the large number of dominant factors which are contributed by each parent so that in general the offspring seem to be intermediate; or it may be due to the fact that neither allelomorph of a pair completely dominates the other in which case there should be a segregation of parental characters in the F_2 generation. In the classical cases of Mendelism the varieties crossed differ in only a few characters. Linnean species, however, differ in very many characters and if the dominant characters are pretty equally distributed between the two species the result would be that the hybrids would appear to be intermediate. This is in fact one of the most general features of hybrids between species. If such intermediacy is really the result of the combination of large numbers of contrasting characters, or rather of their genes, the F_2 generation should present a large number of segregations and therefore wide variability. Owing to the large number of contrasting characters or allelomorphs in different species the number of possible combinations in the F_2 generation is very great (p. 174) and immense numbers of offspring are necessary in order to determine whether or not all these possibilities are realized and still larger numbers are needed to determine the *relative* numbers of these different types.

Thus the *smallest* number of offspring which would represent the Mendelian ratios of different types, where one allelomorph completely dominates the other, would be for

1	pair	of	Allelomorphs,	4	F_2 individuals.
2	"	"	"	16	" "
3	"	"	"	64	" "
4	"	"	"	256	" "
5	"	"	"	1,024	" "
6	"	"	"	4,096	" "
	Etc.				

Of course a much greater number than that must actually be observed if the ratios are to be determined with any approach to accuracy. For example, in determining the simple 3 : 1 ratio in the cross of yellow-seeded and green-seeded peas, Mendel observed 6,022 yellow seeds and 2,001 green seeds and 15 different investigators who have made this cross have recorded in the F_2 generation a total of 152,824 yellow-seeded to 50,676 green-seeded peas which makes the ratio 3.004: .0996 or very nearly 3 : 1. (See Morgan, 1919, p. 24.) It would therefore be an enormous labor to determine with any accuracy the relative numbers of different types which would result where there were even five or six pairs of allelomorphs.

For example, Baur has determined the existence of more than 20 different factors for the color and form of flowers in the snap-dragon *Antirrhinum.* Lotsy crossed two species of snap-dragon, *A. majus* × *A. molle;* the F_1 hybrids were intermediate in all respects and were completely fertile; out of an F_2 population of 255 plants, he distinguished about 25 different flower types, besides many other character differences such as size, form of leaf, habit of growth, etc. One of these F_2 plants produced 209 plants of the F_3 generation all of which had different types of flowers, but wherever single pairs of allelomorphs could be recognized and followed it was found that their segregation in the F_2 and subsequent hybrid generations approximated the Mendelian ratio of 3 : 1.

Detlefsen obtained essentially similar results in crossing two different species of the guinea pig, *Cavia porcellus* × *C. rufescens.* He studied in particular five pairs of contrasting characters in the color and arrangement of the hair and as a result of this work he concludes that in the hybrids of these species inheritance is Mendelian.

b. Infertility.—But another and even greater difficulty in determining whether species-crosses are Mendelian or not results from the fact that such hybrids are frequently but not invariably more or less infertile. If certain combinations of allelomorphs should be sterile or less fertile than others it would cause wide departures from the expected ratios and in cases where infertility of hybrids is the rule, it is of course impossible to determine whether or not Mendelian segregation occurs. There are however many cases in which such hybrids are fertile and in all such cases there are evidences that inheritance is Mendelian. On the whole there is no good reason to suspect that species-crosses differ fundamentally from variety-crosses in this respect.

4. Unequal Reciprocal Hybrids

In typical Mendelian inheritance reciprocal crosses yield identical results. Thus it does not matter in a cross between white and red guinea pigs whether the male is white and the female red or *vice versa;* the results are the same in either case. But in some instances reciprocal crosses yield different results. Thus the cross between the male ass and the female horse yields a mule, but the reciprocal cross between the female ass and the male horse produces a hinney. When the hybrid resembles the father more than the mother it is said to be "patroclinous"; when the reverse is true it is "matroclinous." Such unequal reciprocal hybrids have been studied especially in the Œnotheras by de Vries and he comes to the conclusion that they are due to the fact that the male and female gametes of a species may carry different factors—that they may be heterogamous as contrasted with the more usual conditions where they are isogamous. The cause of heterogamy is obscure, but de Vries suggests that the pollen which receives maternal factors, for example, may remain rudimentary so that all the active pollen carries only paternal factors while the reverse may be true of the egg cells.

The extensive work which Morgan and his associates have done on lethal factors in *Drosophila* shows that they play an extremely important part in the non-survival of certain gametes or zygotes. They have demonstrated that a number of such lethal factors are located in the X chromosome and that all individuals in which such a factor is not balanced by a normal allelomorph die early. All males that receive such a factor die since there is only one X chromosome in the male; all females that receive it in both X chromosomes die, while only those survive that have such a lethal factor in one or neither of the X chromosomes.[3]

[3] Bridges has shown also that patroclinous sons and matroclinous daughters may result from a phenomenon which he calls "non-disjunction," that is the failure of certain pairs of chromosomes to separate during the maturation of the germ cells.

In some such manner as this it may be possible to explain the condition of heterogamy and unequal reciprocal hybrids. Such hybrids therefore do not disprove the Mendelian law but they furnish additional and unexpected support for it when they are properly analyzed. We may therefore conclude that the Mendelian law of heredity, especially as regards the segregation of inheritance factors, is of universal occurrence—that there is no other type of inheritance.

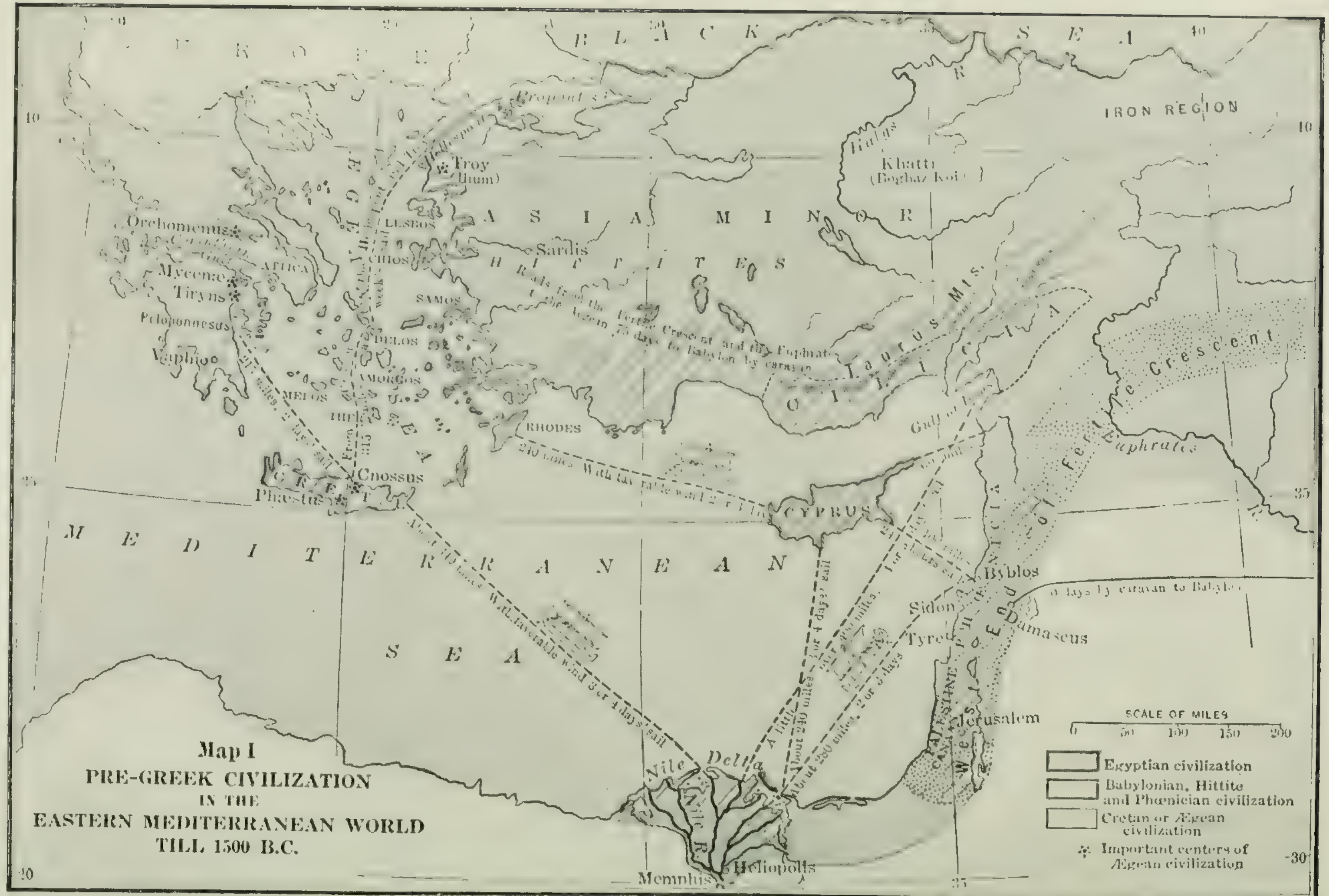


FIG. 85. MAP OF THE EASTERN MEDITERRANEAN, SHOWING ESPECIALLY THE RELATIONS OF EGYPT AND THE ÆGEAN. (From the author's "Ancient Times," by permission of Ginn & Co.)

THE ORIGINS OF CIVILIZATION[1]

By Professor JAMES HENRY BREASTED
THE UNIVERSITY OF CHICAGO

LECTURE TWO

THE EARLIEST CIVILIZATION AND ITS TRANSITION TO EUROPE, II

Just as the Central American culture, particularly in Yucatan, was in close contact with Cuba in pre-Columbian times, so the shipping of the Pharaohs in the Pyramid Age maintained frequent intercourse with Crete. The map (Fig. 85) shows us how Crete, the southeastern island outpost of Europe, is thrust far out into the Mediterranean toward Egypt, almost opposite the mouths of the Nile. This intercourse was facilitated by favoring winds and currents making the three hundred and forty mile interval a matter of a few days' sail. Thus the products of the Nile craftsmen began to find their way into Crete after 3000 B.C.

It can be no accident that the appearance of metal in Crete and on the neighboring mainland of Asia coincides in date with the appearance of the first sea-going ships built by the Pharaohs. The peculiar copper dagger of Egypt, ornamented with lines diverging from a central rib, passed across Europe and

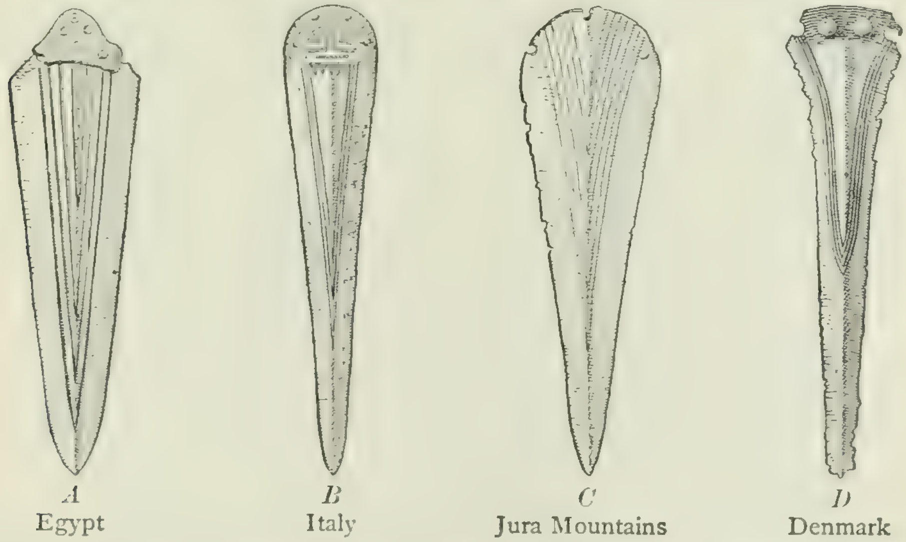


FIG. 86. COPPER DAGGERS OF EGYPT AND EARLY EUROPE, SHOWING THE TRANSITION OF METAL FROM THE NILE VALLEY TO EUROPE. (From the author's "Ancient Times," by permission of Ginn & Co.)

[1] Delivered before the National Academy of Sciences in Washington, D. C., April 28 and 29, 1910, as the seventh series of lectures on the William Ellery Hale Foundation.

FIG. 87. EGYPTIAN GLAZED BEADS FOUND IN AN EARLY BRONZE AGE BURIAL IN ENGLAND. (After Sayce in *Journal of Egyptian Archæology*, Vol. I.)

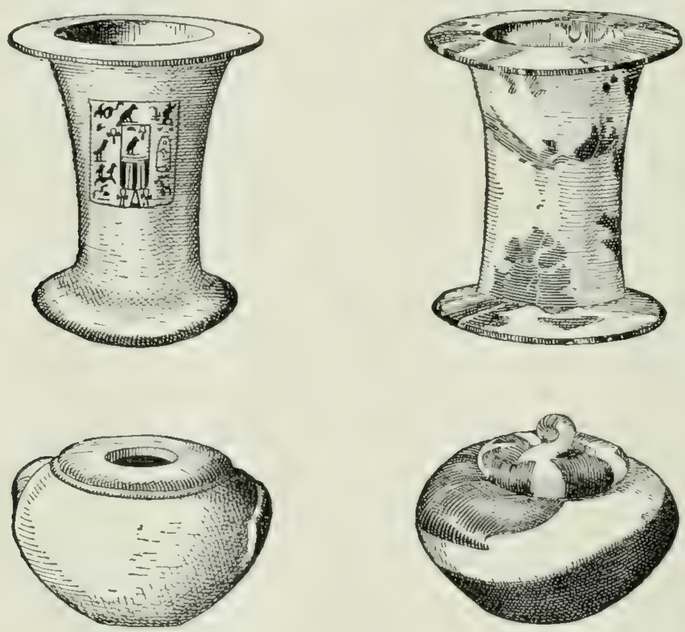


FIG. 88. STONE VASES OF EGYPT (LEFT) AND OF CRETE (RIGHT) IN THE PYRAMID AGE, SHOWING HOW THE EARLY CRETANS REPRODUCED EGYPTIAN FORMS. (From the author's "Ancient Times," by permission of Ginn & Co.)

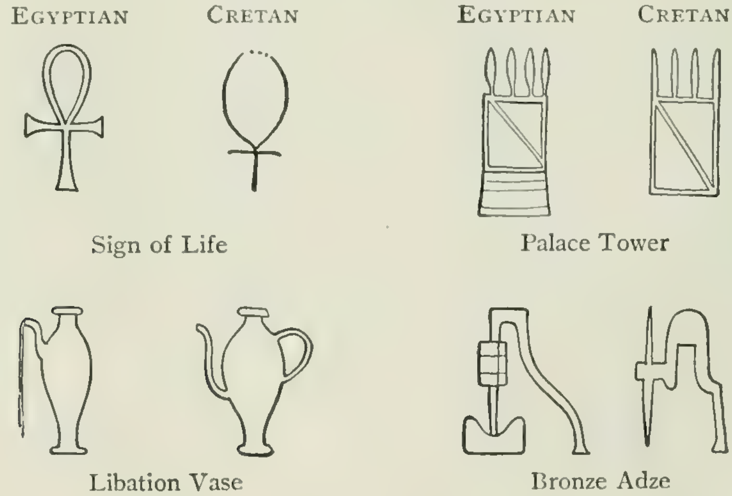


FIG. 89. EGYPTIAN HIEROGLYPHICS COMPARED WITH SIGNS FROM EARLY CRETAN WRITING. (After Sir Arthur Evans.) The signs are arranged in pairs with the Egyptian sign on the left and the corresponding Cretan sign on the right.

penetrated as far north as the Scandinavian countries (Fig. 86), and Egyptian glazed beads have been found as far westward as the Neolithic or Early Bronze Age graves of the British Isles (Fig. 87). The beautiful stone vases wrought by the skilled craftsmen of the Pyramid Age with their new tubular drill (Figs. 73–74), roused the emulation of the gifted Cretans, and they presently succeeded in making very clever copies (Fig. 88). As a result of such endeavors thriving industrial communities, exhibiting surprising native capabilities and artistic gifts, arose in Crete, and their copying, quite freed from any slavish imitation, began to display a vigorous and creative individuality which brought forth the earliest civilization on the southeastern fringes of Europe.

This new Cretan civilization, revealed to us especially by the brilliant discoveries of Sir Arthur Evans at Cnossus, and also by very creditable American excavations, continued to develop after 2000 B.C. in close contact with the Oriental life on the Nile. As the Cretans developed their own writing, the connection with Egyptian hieroglyphic is evident, as Sir Arthur Evans has showed (Fig. 89). After the expansion of Egyptian power into Asia and the Mediterranean in the Feudal Age (or Middle Kingdom, flourishing for two centuries after 2000 B.C.)

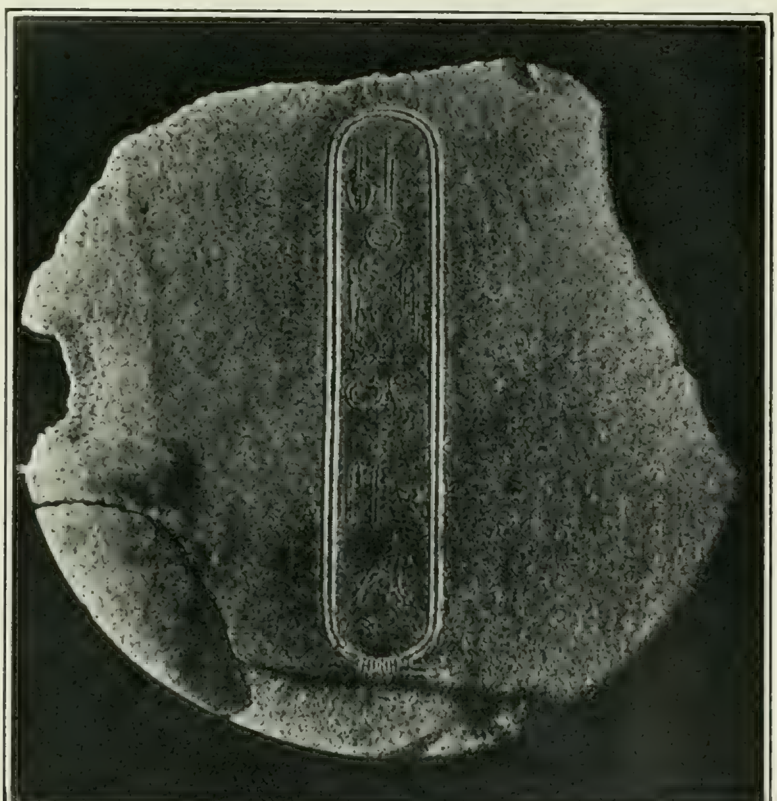


FIG. 90. ALABASTER VASE LID BEARING THE NAME OF THE EGYPTIAN PHARAOH KHIAN FOUND BY SIR ARTHUR EVANS UNDER A WALL OF THE CRETAN PALACE OF CNOSSUS—PROBABLY ABOUT THE 17TH CENTURY B.C.

FIG. 91. A LINE OF CRETAN ENVOYS (THE LOWER ROW) IN EGYPT BRINGING TRIBUTE TO THE PHARAOH IN THE 15TH CENTURY B.C. The scene is taken from a painting on the wall of the tomb of Rekhmire, Grand Vizier of the Pharaoh Thutmose III., the greatest of the Egyptian conquerors.

and the Empire (1580–1150 B.C.), the development of the first great navy enabled Egypt to maintain unchallenged supremacy in the eastern Mediterranean and among the islands of south-eastern Europe. The beginnings of this Mediterranean power of Egypt are suggested by the name of the Pharaoh Khian, engraved on an alabaster vase lid found under a palace wall at Cnossus (Fig. 90).

As the Egyptian Empire established its power in the northern Mediterranean, the Pharaoh appointed a governor over the Ægean Islands. Cretan envoys bringing their tribute to the court of the Pharaoh were a common sight in the fifteenth century B.C. (Fig. 91). Such Cretans who had visited the Nile,

FIG. 92. A CRETAN VASE DECORATED IN RAISED PATTERNS WITH EGYPTIAN FLOWERS. A fine example of the remarkable decorative art of Crete in the Grand Age about the middle of the 15th Century B.C.

and likewise Egyptian wares common in the Cretan markets, brought many a Nilotic motive into the art and life of this remarkable island people which they promptly appropriated. Thus Egyptian flowers like the lotus or the papyrus became common in Cretan art, where they were employed with new life, freedom and vigor, which are a marvellous expression of Cretan ability in decorative art (Fig. 92). This magnificent decorative art of Crete also had its influence on Egypt in return, for the situation was one in which reciprocal influences were inevitable. It is sometimes a question among archeologists as to which was the giver and which the receiver (Fig. 93).

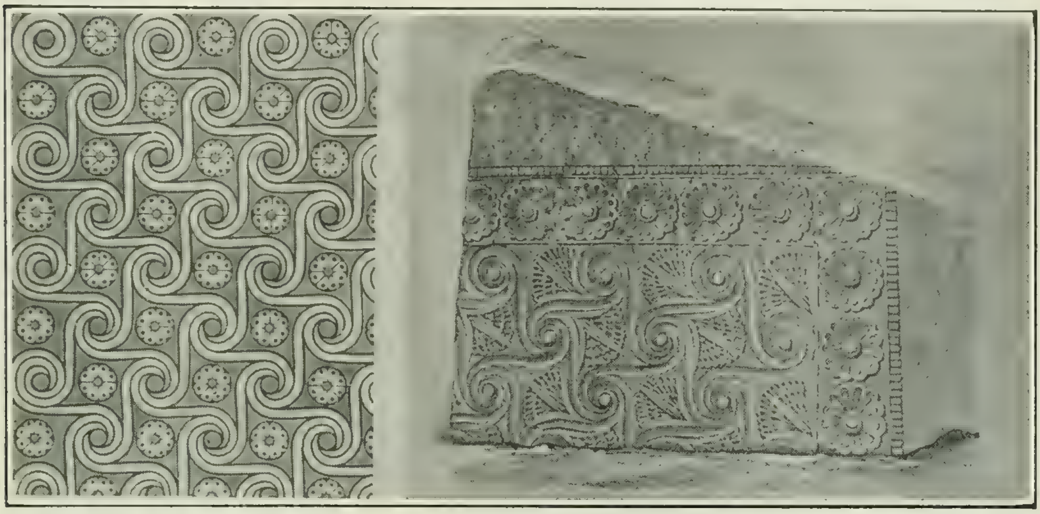


FIG. 93. CEILING DECORATIONS OF EGYPT AND MYCENÆAN EUROPE. The Egyptian pattern (on the left) is from a painted ceiling in an Egyptian tomb at Thebes (Egypt), while the Mycenæan design was carved on a tomb ceiling at Orchomenos in Greece, and belongs to the outgoing Ægean art of the period when the Greeks were already taking possession of the Ægean world—the period which was called Mycenæan after Schliemann's discoveries at Mycenæ.

While the highly developed arts and crafts of Egypt furnished the Ægean world with the devices and the technical processes for carrying on a flourishing industrial life, the architecture of the Nile did not leave a noticeable mark on the fringes of Europe until the Greek Age which we are now approaching. The limited power and resources of the Cretan state or states would not have permitted any Cretan ruler to vie with the vast monumental architecture of the Nile. The gigantic clerestory hall of the Karnak temple (Fig. 94) was a structure possible only to a ruler of imperial wealth and resources, commanding a highly efficient body of architectural engineers such as existed at this time nowhere outside of Egypt. It is impossible in this brief presentation to do more than suggest in terms of such architecture as this, the imperial development which went on in Egypt after the sixteenth cen-

FIG. 94. COLUMNS OF THE GREAT KARNAK CLERESTORY HALL. A hundred men can stand on the capital of each column of the nave.

tury B.C. (Figs. 95–96). The resources and impulses which had prompted this great expansion of Egyptian life and power were exhausted by 1200 B.C. and fifty years later Egypt was nationally prostrate and powerless.

A similar development of human life had meantime been going on in Western Asia, and if we have been late in reaching it, this has been chiefly due to the fact that the Babylonian world of the lower Tigris and Euphrates lay separated from the Mediterranean by a great northern extension of the Arabian desert over five hundred miles across. Babylonian civilization, thus cut off from immediate contact with the Mediterranean world and Europe, was later in affecting the tide of Oriental influences which for ages pressed upon the life of Europe and the West, and in Hebrew and Christian religion has not yet ceased to do so. Another reason which has delayed us in taking up Western Asia is found in the fact that the *prehistoric* development of the region, as we have already stated, has yet to be investigated, and as a whole to be recovered from the still inaccessible and undiscovered sources. But Babylonian influence was not less great and important because it was somewhat later than that of the Nile.

A glance at the map shows us that southern Babylonia and northern Egypt are practically in the same latitude. Yet their respective situations are totally different. Egypt, strategically considered, is surprisingly protected from invasions and assaults of foreign peoples. Its isolated situation due to the wastes of the great Sahara on each side and the Mediterranean on the north, enabled it to enjoy a continuous development uninterrupted by foreign intrusion for many centuries at a time. In an age when maritime peoples were still unknown on the Mediterranean, this body of water was a protecting barrier against the Stone Age barbarians of the north, of enormous importance to Egypt, and to this freedom from invasion at the hands of the backward northern peoples, we

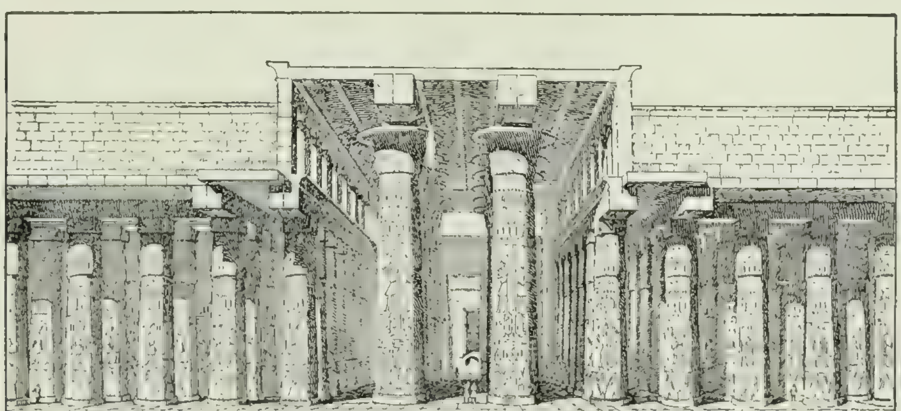


FIG. 95. RESTORATION OF THE GREAT KARNAK CLERESTORY HALL. Built chiefly by Ramses II. in the 13th century B.C., some 1,500 years after the incipient clerestory of Khafre at Gizeh (Fig. 79), it represents the culmination of a long development which has brought forth tall and stately clerestory windows in place of primitive light-chutes, and imposing colonnades in place of rectangular piers (Fig. 80). From such Egyptian temple halls the basilica structures of Hellenistic and Christian Europe have descended.

FIG. 96. ONE OF THE COLOSSAL PORTRAIT STATUES OF RAMSES II. ADORNING THE FRONT OF THE CLIFF TEMPLE OF ABU-SIMBEL ON THE NILE IN NUBIA. There are four such figures along the front of the temple; each is seventy-five feet high.

may attribute in no small degree Egypt's advance to civilization at a time when no such great civilized nation had appeared anywhere else.

The alluvial plain on the lower Tigris and Euphrates, which we call Babylonia, was, on the other hand, continually exposed to invasion by the less developed peoples of the mountains on the north and east. At the same time the nomad population, which still finds pasturage for its flocks along the northern fringes of the Arabian desert, beset Babylonia with a similar unceasing menace from the other side. The history of western Asia is often made up of the struggle between the mountaineers on the north and the desert nomads on the south, for the possession of the Fertile Crescent which lay between, and of which Babylonia forms the eastern and Palestine the western end. It was therefore impossible for any people occupying the Babylonian Plain to develop without interference in accordance with its own capabilities and native gifts. The civilized development here was repeatedly halted and sometimes stagnated, as it has done in modern times, for centuries. This was not seldom due to the further fact that the *invasions* were often at the same time *migrations* bringing in a relatively large body of foreign population.

Retarded from prehistoric times by the rigor of the northern winters and the cold of the outgoing glacial age, western Asia was far behind Egypt at the opening of the fourth millennium

FIG. 97. EGYPTIAN RELIEF (LEFT) OF THE 30TH CENTURY B.C., SHOWING THE STANDING FIGURE OF AN EGYPTIAN NOBLE, AND EARLY SUMERIAN RELIEF (RIGHT), SHOWING THE FIGURE OF A SUMERIAN CITY KING OF THE SAME AGE. We have here an opportunity to compare the art of the two cultures at the same age. It may be noted that the Babylonian relief is a royal monument while that of Egypt is from the tomb of a noble only.

FIG. 98. THE CENTRAL PORTION OF THE MOUND OF THE OLD SUMERIAN CITY OF NIPPUR, NOW CALLED NIFFER, IN CENTRAL BABYLONIA. The highest portion of such mounds covers the public buildings and especially the temple mount or tower. (By courtesy of the University Museum, Philadelphia.)

B.C., and the prehistoric advance of Babylonia was for the reasons mentioned above so slow that in the thirtieth century B.C. her culture was still noticeably inferior to that of Egypt (Fig. 97).

The earliest towns on the Babylonian alluvium were rarely more than a few hundred paces across. They were built of sun-dried brick and as a result of the action of weather and successive destructions at the hands of hostile invaders, a considerable volume of disintegrated brick accumulated as the centuries passed. This rubbish was not cleared away when the new buildings were put up, and hence the town finally stood on a high mound (Fig. 98). Such a mound is called by the Arabs a "tell," a word which therefore appears very commonly in the geographical names of Egypt and western Asia. Traversing the Babylonian plain to-day the modern traveler is rarely out of sight of such a mound somewhere on the horizon. These are the treasuries whence the evidence for the reconstruction of early Babylonian life and history is chiefly drawn. Thus far only a small proportion of the early Babylonian mounds has been excavated and thoroughly investigated. Indeed the rigorous methods of Mediterranean archeology have only recently and in limited measure, begun to be applied to Babylonian research.

Each one of these mounds represents an early city-kingdom consisting of the town and a fringe of outlying fields. You could have walked across the whole kingdom in an hour or two. At the head of this petty realm was a king, whose monuments, excavated from the mound now covering his town, sometimes reveal him to us in primitive sculpture engaged in the ceremonious functions of his little state (Fig. 99).

The people over whom he ruled are called Sumerians in the documents of the time. While their racial origin is still uncertain, it is evident that they were not Semites, like the nomads of the neighboring desert, and their affinities are therefore to be sought in the mountains. Well back in the fourth millennium B.C. they had developed their own writing. Like the writing

FIG. 99. AN EARLY SUMERIAN CITY KING OF THE 30TH CENTURY B.C. ENGAGED IN PUBLIC CEREMONIES. The relief is engraved on the limestone base of some ceremonial object, presumably a mace, the handle of which was thrust into the hole in the middle of the block. In the upper relief the king is seen standing at the left with a basket probably filled with earth on his head. Before him in a line his children approach, and behind him is his cup-bearer. The ceremony is probably that of beginning the digging for some important public work like a canal or the foundation of a temple. Below the king is seated at the right with much the same personages about him. The birdlike features and crude drawing evince the primitive and undeveloped character of the art. The inscriptions in cuneiform record the names of the individuals shown. That of the king was Urnina, a ruler of Lagash.

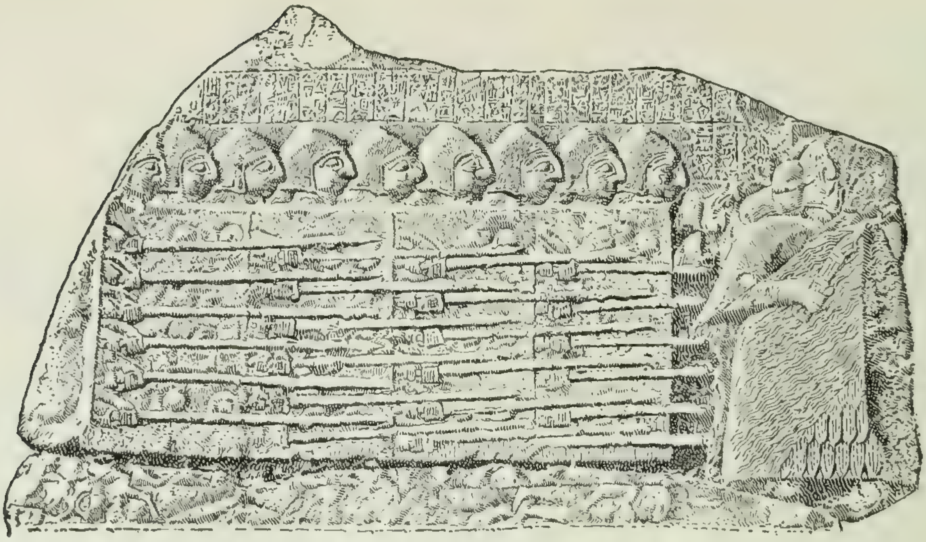


FIG. 100. A SUMERIAN PHALANX. This relief of the 29th century B.C. is a fragment of a round-topped stela commonly called the Vulture Stela, recording the victories of Eannatum, king of Lagash. The scene shows him at the head of a phalanx of the troops of his little city-kingdom.

of Egypt it grew up out of picture signs. As a result of the process of writing on soft clay tablets, the individual lines of the pictures assumed the forms of wedges, and for this reason the writing of these people has been called *cuneiform* (Latin *cuneus*, "wedge"). It never developed alphabetic signs. The Egypto-Babylonian culture group thus devised two physical processes of writing: the one by tracing the characters with a pen and a dark pigment on a vegetable membrane; the other by impressing or incising the characters on a soft or plastic substance. The latter process, that of Asia, survived for a time in

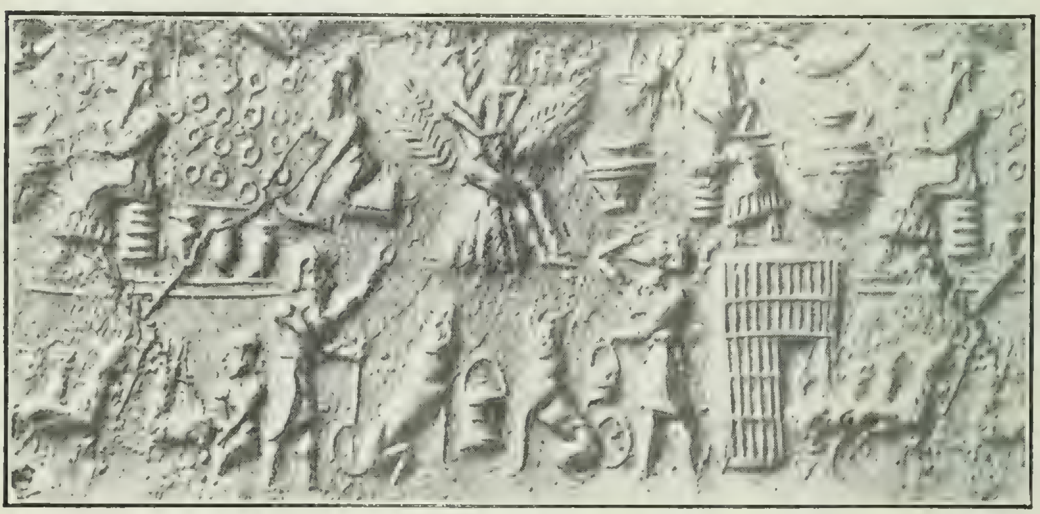


FIG. 101. EARLY SUMERIAN CYLINDER SEAL IMPRESSION SHOWING THE FIGURES OF ANIMALS IN BALANCED OR ANTITHETIC ARRANGEMENT. It must be remembered that these tiny figures were cut by the lapidary around a cylinder of hard stone not thicker than one's finger, and sometimes much smaller, and perhaps only half as long. They represent a great and noble art in striking contrast with the feebleness of the sculptor in relief (Fig. 99).

the clay tablets of Crete and the waxen tablets of the Roman gentleman, and then perished; the other, the method of Egypt, still survives in the pen, ink and paper of modern usage.

These Sumerian city-kingdoms had already gained agriculture and were practising it in the fourth millennium B.C. Their oldest documents mention emmer, wheat and barley as everyday matters. The occurrence of wild wheat, or emmer, which was the ancestor of domesticated wheat, growing in a wild

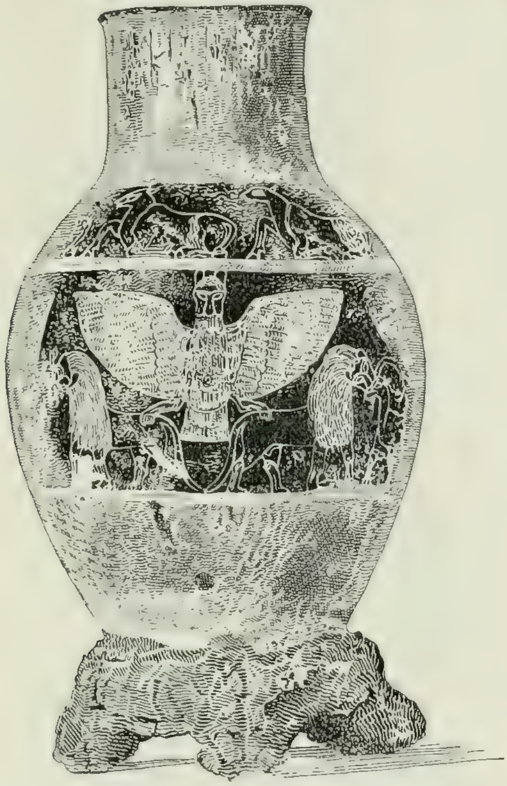


FIG. 102. AN EAGLE SURMOUNTING TWO ANTITHETICALLY PLACED LIONS FORMING THE ARMS OF THE CITY OF LAGASH. Engraved on a silver vase of king Entemena of Lagash in the 29th century B.C. It forms a fine example of early Babylonian heraldic art.

state in western Asia as far east as the Kermanshah Pass, may yet lead to the conclusion that it was domesticated in Babylonia, but we must make the botanical exploration of the Near East more nearly complete before this question can be finally settled. That wheat and barley were domesticated by the Egypto-Babylonian group and passed thence into Europe is, however, perfectly clear.

Cattle and sheep were likewise possessed by these people long before 3000 B.C. Further investigation of the culture levels of the fourth millennium, still almost untouched, will be necessary before we can reach final conclusions regarding the sources of these animals. It is interesting to observe that the Sumerians already possessed the wheel as a burden-bearing device, so that they were able to build wheeled carts. It is pos-

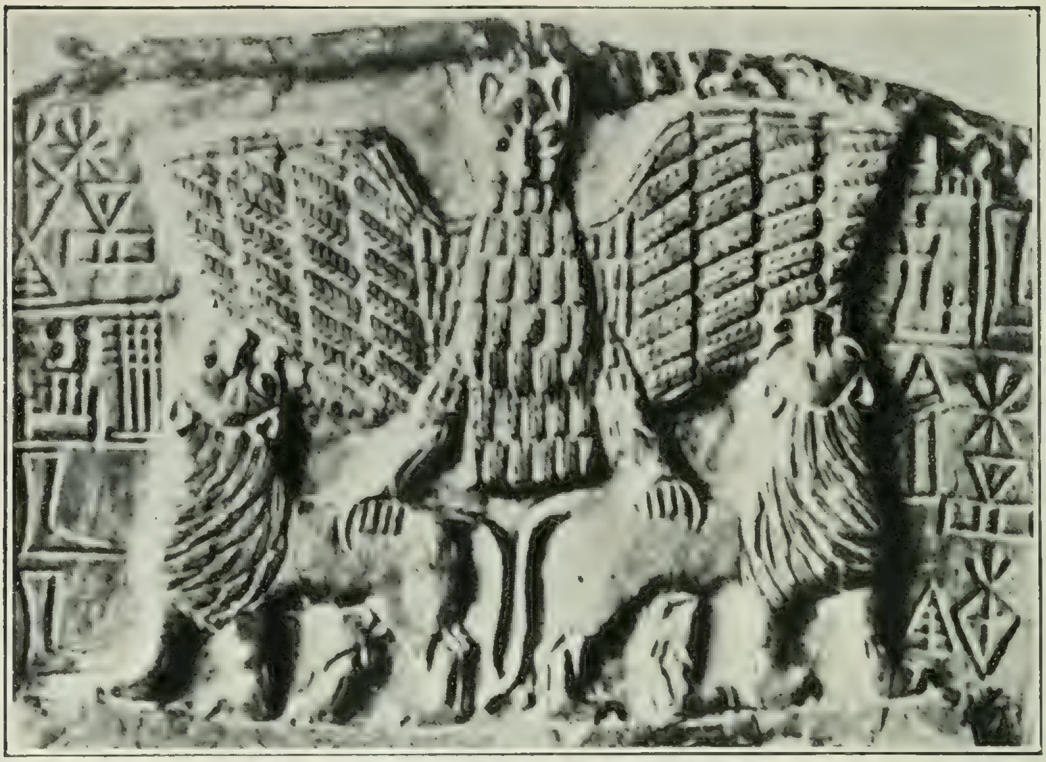


FIG. 103. THE ARMS OF LAGASH AS SHOWN IN FIG. 102, FROM A PLAQUE OF BITUMINOUS CLAY.

sible that they already employed the ass to draw such carts. In any case they possessed the animal in a domesticated state, a fact which points toward connection with Egypt. At the same time they came into possession of copper. The earliest dated pieces of copper in Asia are a thousand years later than the copper needles of the earliest graves in Egypt, and it is evident where we must look for the original home of metallurgy.

These early Sumerian city states were constantly embroiled in petty wars among themselves. The art of warfare among them had reached an extraordinarily high development, far superior to that of Egypt. It is a justifiable generalization to say that the arts of peace were developed chiefly in Egypt, while those of war were due to the peoples of western Asia, especially the Sumerians and Assyrians. We find the Sumerians already employing the phalanx as early as the twenty-ninth century B.C. (Fig. 100). The Egyptian monuments show that this formation had reached the Mediterranean by the twelfth century B.C., and there can be no doubt that the later Greek phalanx was inherited from the ancient Sumerians. It may be a fair question whether the existence of this formation among the Sumerians at such an early date does not point to a western origin for them somewhere in Asia Minor, whence their military experience was easily communicated to Europe.

While early Sumerian art as exhibited in sculpture was at first crude and backward (Fig. 99), the Sumerians developed a decorative art of epoch-making importance. It was practised with the greatest success by the lapidaries, who were called upon to produce the stone cylinder seals employed by the Sumerians to seal their clay documents. The content of this decorative art was chiefly animal and human figures arrayed in a balanced or antithetic arrangement (Fig. 101), which we have already seen in the prehistoric art of Egypt (Fig. 63). As employed by the Sumerians these groups were given startling vigor and power by depicting the figures in violent motion or engaged in tremendous muscular effort. Thus arose the heraldic art familiar to us all in the "lion and the unicorn." The Sumerians therefore contributed to the decorative art of the world a rich treasury of powerful forms to which it has ever since been indebted.

FIG. 104. BALANCED ANIMALS, EGYPTIAN, SUMERIAN AND ÆGEAN. Antithetically placed animal figures were common in the art of Egypt from the remotest times, probably earlier than in Babylonia, as noted in Fig. 63. They are a conclusive evidence of the culture diffusion within the Egypto-Babylonian group, whence such influences passed to the Ægean as shown in the last figure of the three.

Among such figures is that of an eagle with its wings and talons extended in antithetic arrangement. With its talons the bird at the same time clutches the backs of two lions, likewise antithetically placed (Figs. 102 and 103). The lions sometimes turn their heads and set their teeth savagely into the outspread pinions of the eagle. This device formed the emblem of the Sumerian city of Lagash, that is, what we should now call the arms or armorial bearings of the little kingdom. The eagle with outspread wings early passed into Asia Minor (or is this another evidence of the origin of the Sumerians in Asia Minor?), and thence into the Ægean (Fig. 104) and Europe, where we are familiar with it in the arms of the southeast European states, like Austria. It eventually reached the German states, like Bavaria and Prussia, and later also Russia and France. It was from these European sources that we drew our own American eagle, for the earliest ancestry of which we must therefore go back to an ancient Sumerian city-state.

Lack of stone in Babylonia prevented the development of such massive monumental architecture as we have found on the Nile. The Sumerian builder was dependent exclusively upon brick, chiefly sun-dried, but occasionally baked to protect the faces of his larger structures from the destructive action of rain. His buildings were almost all small and unpretentious. He never undertook a treatment of the void, such as developed the piers and colonnades of Egypt. Western Asia was therefore entirely without the column until Greek times, notwithstanding the elaborate colonnades with which Ferguson and other historians of architecture have embellished their restorations of western Asiatic buildings. The Sumerian architect's

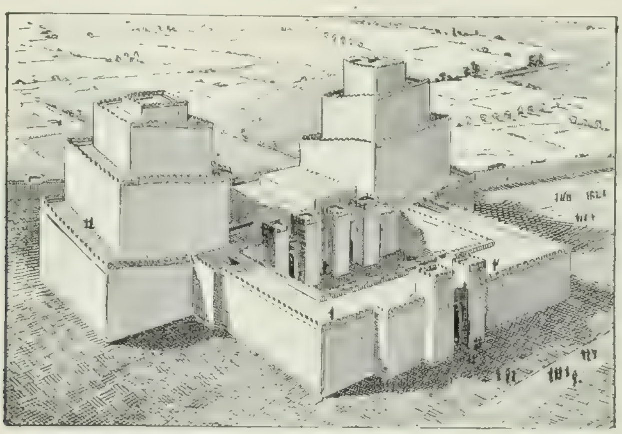


FIG. 105. A PAIR OF EARLY ASSYRIAN TEMPLE TOWERS, ILLUSTRATING THE TEMPLE TOWER OF THE SUMERIANS. (After Andræ.) Such towers were not commonly erected in pairs. These two belonged to the double temple of Anu and Adad in the city of Assur, and as restored by the excavators they serve very well to illustrate the earlier Sumerian temple towers. It was such a structure which gave rise to the tradition of the tower of Babel. From it have descended the prevailing types of tower and spire architecture in Europe (see Fig. 126).

Fig. 106. Monument of Victory of the Semitic King Naramsin of Akkad: the earliest great Semitic work of art (28th century B.C.). The king, whose figure is depicted in heroic proportions, has pursued the enemy to the summit of a mountain. The artist has selected the dramatic moment when the foe has surrendered and the king indicates his merciful intentions by lowering the point of his weapon.

device for carrying the wall or the roof over the void was the arch and the vault, and he never made wider interiors than he was able to span with his vault. It was from the buildings of western Asia, as we shall see, that the arch was transmitted to Europe.

FIG. 107. IMPRESSION FROM A BABYLONIAN CYLINDER SEAL OF AKKADIAN AGE IN THE OLD SUMERIAN MANNER. (Collection de Clercq.)

While the Sumerian made no contribution to the treatment of the *void*, he was the more successful in his handling of the *mass*. He broke up the monotonous surfaces of his brick walls by a rhythmic distribution of alternate panels and pilasters. As to the form of the mass he made a real contribution in the artificial temple mount erected alongside the sanctuary in the form of a rectangular tower with an ascending ramp winding about it from base to summit by which the priest climbed to the top (Fig. 105). This structure, which gave rise to the legend of the Tower of Babel, marked the entrance of the tower into architecture. From it have descended the leading tower forms of the West, as we shall see.

It will be seen that Sumerian civilization made fundamental contributions to the life of man, to which we are still indebted. The exposed situation of their home, however, as we have already stated, made it impossible for them to continue an uninterrupted development. The Semitic nomads who drifted down the Two Rivers, were strong enough to set up a small kingdom in the district of Akkad, the northern portion of the Babylonian Plain. We can trace the career of the Sumerian city-kingdoms from their earliest emergence in the thirty-first century B.C., for about three centuries, and then in the middle of the twenty-eighth century the Semitic rulers of Akkad contributed the first great Semitic leader in history, whom we now call Sargon of Akkad. Although these Akkadian Semites were obliged to make the revolutionary transition from the primitive nomadic life of the desert without writing, arts or institutions, to the civilized life of the Sumerian towns, in short to shift from the tent to the sun-dried brick house, they eventually outstripped their Sumerian teachers, on whom they were at first completely dependent.

Under Sargon they were so completely master of the Sumerian art of war that they gained the leadership of the Babylonian Plain, and the descendants of Sargon continued to rule there for some two hundred years. A noble stela recording the victories of Naramsin, an able ruler of this line, reveals to us the superiority of the Semitic Akkadian in art (Fig. 106). It is the first great Semitic work of art. A comparison with Fig. 99 will demonstrate how far the art of Babylonia had advanced since the early days of the Sumerian city-kingdoms. The Semite displayed his superiority in the same way in the magnificent cylinder seals of the time (Fig. 107). These, like the relief of Naramsin (Fig. 106), belong among the great works of art of all time.

While the Sumerian towns regained the leadership and

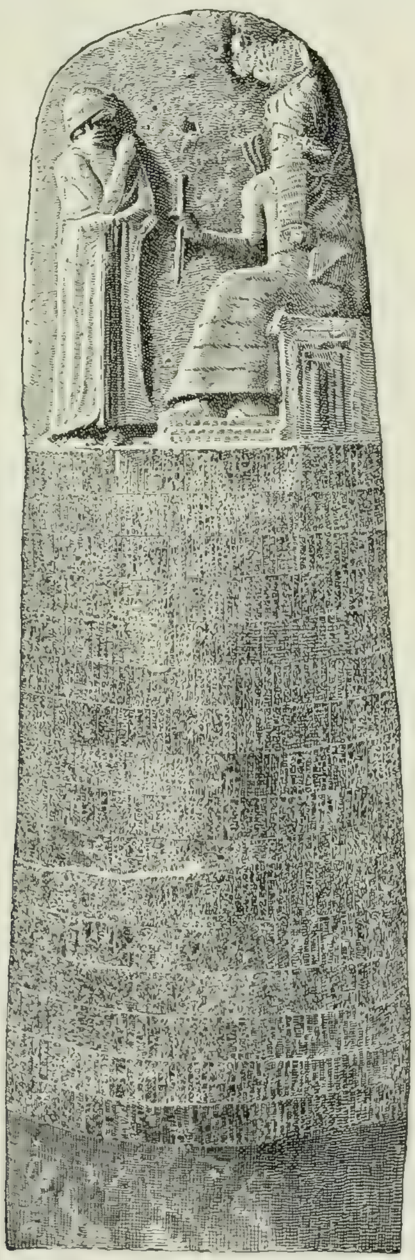


FIG. 108. DIORITE SHAFT BEARING THE GREAT CODE OF HAMMURAPI (early 21st century B.C.). (Compare Fig. 132.)

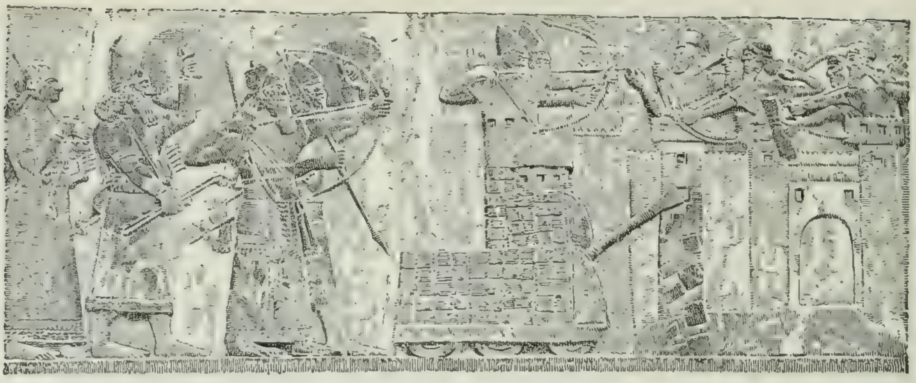


FIG. 109. A SIEGE ENGINE OF THE ASSYRIANS IN THE NINTH CENTURY B.C. A city at the right is being attacked by the Assyrian machine seen in the middle. The machine is on wheels operated by men concealed within. A turret with peep holes protects the commander of the machine, and a firing tower (also with peep holes) is occupied by two archers at the top. A heavy metal-tipped beam (which later passed to Europe as the "battering ram") is swung by concealed men against the walls and the results are seen in the falling fragments of the wall. It will be seen that this is a man-power tank lacking only gunpowder and gasoline power to make it a modern tank. Note the armor on front, over turret and around the firing tower. The scene is from a relief adorning the palace of King Assurnacirpal, and now in the British Museum.

struggled for centuries with waning power, to maintain it, the rise of a new Semitic line, living at the still insignificant town of Babylon, completely crushed the Sumerians and they never after regained the leadership of the region. Like Latin in the medieval church, their language still survived, especially in the literature of religion, and their cultural contributions had long since become a permanent element of western Asiatic civilization. The life of their towns, however, languished and declined, never to rise again. They are marked to-day by a line of mounds along the lower Euphrates, most of which still await excavation.

The powerful Semitic line which had elevated Babylon to the leadership of the plain to which the city gave its name, culminated in the rule of Hammurapi after 2100 B.C. A remarkable monument of this great man's administrative ability has survived to us in the splendid shaft bearing his code of laws in 3,600 lines, the earliest surviving code (Fig. 108). It is a remarkable expression of that ability to organize the material interests of life, especially business and commerce, which as we shall see, later contributed essentially to the rising civilization of Europe.

The reign of Hammurapi, which unified Babylonia and a considerable outlying region round about it, was the culmination of a thousand years of civilized development, from the thirty-first to the twenty-first century B.C. This is the first thousand years of which we can discern the general historical

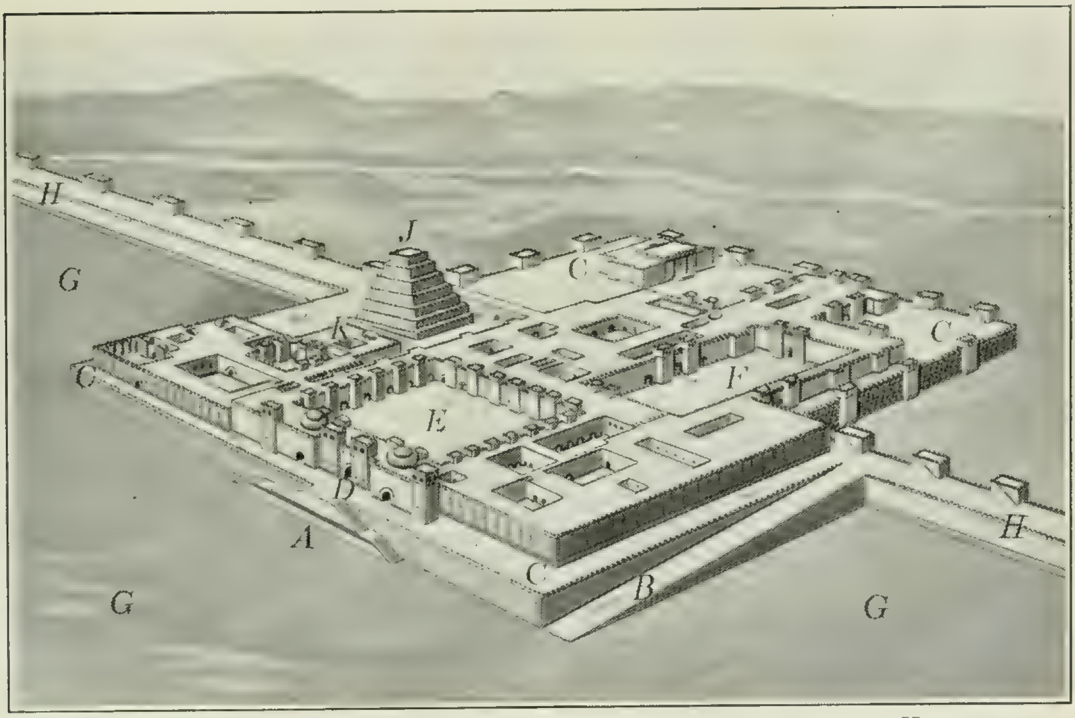


FIG. 110. RESTORATION OF THE GREAT PALACE OF SARGON II. AT KHORSABAD.—Eighth century B.C. (After Place.)

drift in western Asia. Hammurapi's successors were not able to maintain the unity of Babylonia, and the Semite yielded the leadership of the plain for many centuries to non-Semitic mountaineers, a new group of invaders of uncertain race whom we call Kassites. They were little better than barbarians and under them the life of the Babylonian plain relapsed into a stagnation so lethargic that it did not revive for almost a thousand years after Hammurapi's time.

Meantime another Semitic group which had found lodgment and a convenient stronghold on a spur of the eastern

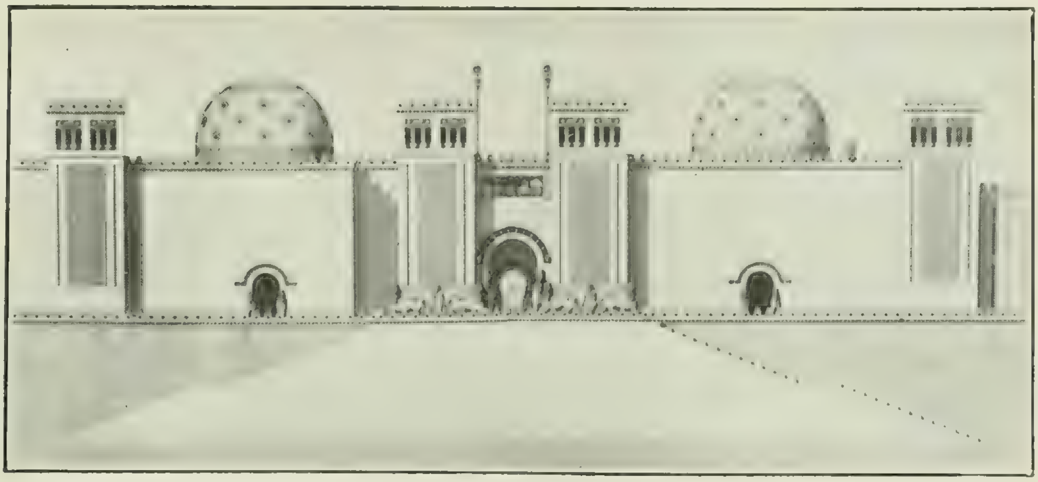


FIG. 111. ARCHED DOORWAYS OF THE FAÇADE OF SARGON II'S PALACE AT KHORSABAD. (Eighth century B.C.) This façade with its three arches was the ancestor of the Roman triumphal arch (Fig. 125), and eventually of the façade of the Christian cathedral with its three arched doorways.

mountains on the upper Tigris, had been developing in obscurity since the days of the early Sumerian city-kingdoms. Its stronghold was known as Assur, from which our familiar designation Assyria has descended. As a result of their exposed situation the Assyrians early produced hardy soldiers; and a nation of peasants and herdsmen, developing on a basis of old Sumerian civilization, with which were combined numerous characteristics of the mountainous north, became the greatest military power, not only of western Asia, but also of the whole ancient world of that age (Fig. 109).

By the middle of the eighth century B.C. the Assyrian kings were ruling a great Western Asiatic Empire, which was advancing its frontiers in almost all directions not limited by the desert. After the fall of the peoples along the eastern Mediterranean coast, including the Hebrews and Phœnicians, in the latter half of the eighth century B.C., the conquests of Sargon II. raised Assyria to a height of power and splendor never before enjoyed by an ancient people. Not far northeast of Nineveh Sargon erected a magnificent palace and city which he called Dur-Sharrukin ("Sargonburg," Fig. 110). It was fitting that this splendid architectural expression of Assyrian power should stand forth as the earliest great monumental architecture of Asia. The old Sumerian buildings, the Syrian palaces, and even the extensive capital city of the Hittites were insignificant compared with it. Its vast staircase, the first great monumental *escalier* in the history of architecture, the spacious arched doorways and enormous sentinel animals of sculptured stone, embellishing the imposing façade (Fig. 111), brilliant with designs in brightly colored glazed brick—all this proclaimed a new imperial age in western Asia. Under Sennacherib and Assurbanipal (Sardanapalus), the walls and splendid palaces of Nineveh stretched for two miles and a half along the banks of the Tigris. National greatness and power, which do so much to quicken the creative imagination of the architect, as we have observed in Egypt, had thus brought forth the first monumental architecture of Asia on a grand scale.

It is a significant fact that the iron mines of northeastern Asia Minor, which had been worked by the Hittites as far back as the thirteenth century B.C., made the Assyrian armies the first great armies of the ancient world to carry weapons of iron. Over against Assyrian ferocity in war, however, even though it was rendered the more dreadful by these terrible weapons, we should in fairness write down not a few other important considerations which essentially alter our estimate of the character and effects of Assyrian supremacy in the ancient world. We can not even summarize these in this slight presentation, but one of them we have suggested in our references to Assyrian architecture, and another which ought not to be overlooked is the presence of a cuneiform library in the palace of Assurbanipal at Nineveh, the earliest known library in Asia, and centuries older than the oldest royal library among the Greeks.

While the Oriental world, or a large part of it, had been slowly coming under the domination of Assyria, the most fundamental changes had been going on in southeastern Europe as far back as the fifteenth century B.C. The pastures of inner Asia which stretch westward around the north end of the Caspian and along the northern shores of the Black Sea to the mouths of the Danube, have for ages been a great inter-continental sluice-way along which the nomadic peoples of Asia have swept into Europe. Somewhere, along the Asiatic stretches of these grass lands in the third millennium B.C., there lived a group of nomads whom we call Indo-Europeans. Some of their descendants shifted southward along the east side of the Caspian to enter India, as the Sanscrit peoples; while a similar group pushed southwestward to reach the frontiers of Babylonia eventually as the Medes and Persians. Others drifting westward along the north side of the Black Sea finally found their way into the Balkan Peninsula. These were the ancestors of the Greeks. Such at least is the more probable reconstruction growing out of the scanty and difficult evidence now available.

Probably by 2000 B.C. these barbarian nomads, the ancestors of the Greeks, were driving their flocks southward through the passes of the Balkans. Reaching southern Greece by 1500 B.C., they had landed in Crete probably by 1400, and before 1000 B.C. the barbarian Greek tribes had taken possession of the remaining Greek islands and the coasts of Asia Minor, in short of the entire Ægean world. Thus the wonderful Cretan civilization which had grown up in southeastern Europe was overwhelmed and crushed by barbarous invaders who had hardly advanced beyond the Stone Age life of earlier Europe. Such of the unfortunate Cretans as were able to do so took to flight, escaping southward and eastward across the Mediterranean. The Pharaohs of the declining Egyptian Empire in the twelfth and thirteenth centuries B.C. were obliged to meet these northern Mediterranean fugitives as enemies, and the temple records of Egypt's wars at this time reveal to us the fleet of Ramses III.

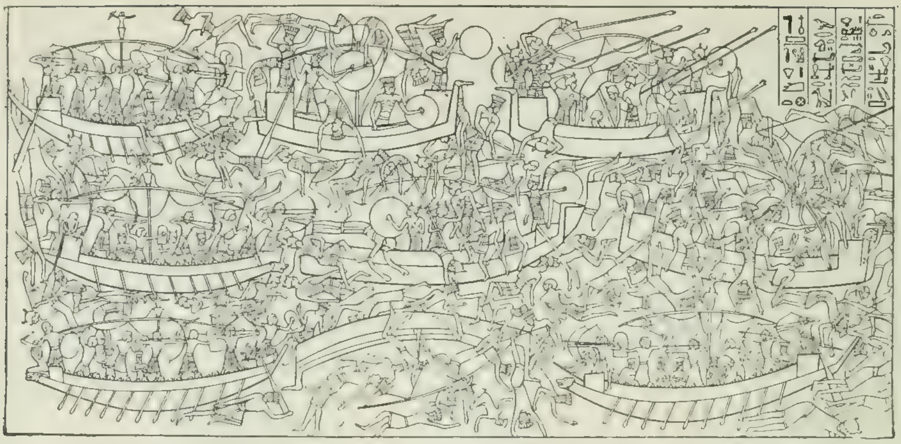


Fig. 112. Ægean Fugitive Fleet driven from Crete by the Greek Immigration and Fighting an Engagement with Egyptian Fleet of Ramses III. off the Syrian coast. (Early 12th century B.C.) The scene is sculptured on the wall of a Theban temple of Ramses III. and is the earliest surviving representation of a naval battle. The five Cretan vessels may be distinguished from the Egyptian battleships by the fact that the Cretans have all lost their oars. One Cretan ship is overturned. The high bow and stern of these northern Mediterranean vessels shows that they have been copied from the early Egyptian craft, the first sea-going ships (Fig. 84). The Egyptian fleet kept its distance and won the battle by the use of archery, before which the heavy armed Cretans were helpless. (From a drawing in the author's "Ancient Times," by permission of Ginn & Co.)

crushing a fleet of the fleeing Cretans. It is the earliest naval battle of which we have any representation (Fig. 112). Some of the Cretans found a new home on the shores of Syria and Palestine and we are familiar with one group of them as the Philistines.

Civilization, after having maintained itself for perhaps a thousand years in extreme southeastern Europe, was thus overwhelmed and blotted out by the northern Greek barbarians, who were only prevented by the Mediterranean from extending their invasion southward and destroying the civilization of Egypt. We have here a striking illustration of how the Mediterranean saved Egypt from a destructive invasion such as those to which Babylonia and the Mesopotamian world were continually exposed. Under the shadow of the great civilizations of the Orient, the rude Greek nomads settled down among the wreckage of the Cretan and Mycenæan palaces. Cretan writing, the earliest writing in Europe, disappeared. The drawings on Greek pottery (Fig. 113) of the eighth century B.C. are not as good as those of the Paleolithic hunters in the caves of southern France ten thousand years earlier, and no better than many made by our own American Indians.

During the flourishing days of the Assyrian Empire, which stopped Greek colonization in Asia east of Tarsus, the life of Greece developed slowly under the influences of Oriental civilization. The civilization which thus arose in Europe *for the* *second time* was exposed to the forces of civilized life in the Near East which had so long been converging with ever increasing power on the Greek world. The agencies by which these influences chiefly operated were commercial, and the routes along which they came were in the main through Asia Minor and across the Mediterranean. Through Asia Minor came Babylonian business usages, like credit, and weights and measures; while coinage, which arose in Asia Minor, reached the Greeks in the seventh century B.C.

The decline of Egypt and the destruction of the Cretan fleets left the Mediterranean free to exploitation by the maritime cities of the Phœnicians, which gained great commercial power and wealth, and became the common carriers of the Mediterranean after 1000 B.C. The Phœnicians were clever imitators and their leading cities became the centers of an active industrial life of which the output was a curious composite of Egyptian and Asiatic elements. The latter were in turn a composite of Sumerian, Akkadian, Assyrian and Hittite, but chiefly Sumero-

FIG. 113. ARCHAIC GREEK PAINTED POTTERY VASE OF THE DIPYLON TYPE DATING FROM THE EIGHTH CENTURY B.C. A comparison of the crude painted decoration on this vase with the wonderful Cretan decorated vases like Fig. 92, will illustrate the collapse of civilization due to the invasion of the cultivated Ægean world by the barbarian Greeks during the latter half of the second millennium B.C. (By courtesy of the Metropolitan Museum of Art, New York.)

FIG. 114. SILVER PLATTER MADE BY PHŒNICIAN CRAFTSMEN AND ENGRAVED BY THEM WITH EGYPTIAN DECORATIVE MOTIVES. Now in the Berlin Museum.

Semitic. Their arts and crafts and industrial processes, like the making of glass, the pouring of hollow casts, and the production of diaphanous linens, they learned from the Egyptians; while their decorative art combined the vegetable motives and the sentinel animals of the Nile with the balanced human and animal figures of the Euphrates (Figs. 114–115).

The Phœnicians learned shipbuilding from the Egyptians and copied the models of the Egyptian ships which had been entering their harbors since the thirtieth century B.C. (Fig. 84). This is quite evident from the paintings of early Phœnician ships preserved to us in the Egyptian tombs (Fig. 116), and dating from the fifteenth century B.C. Against the old tend-

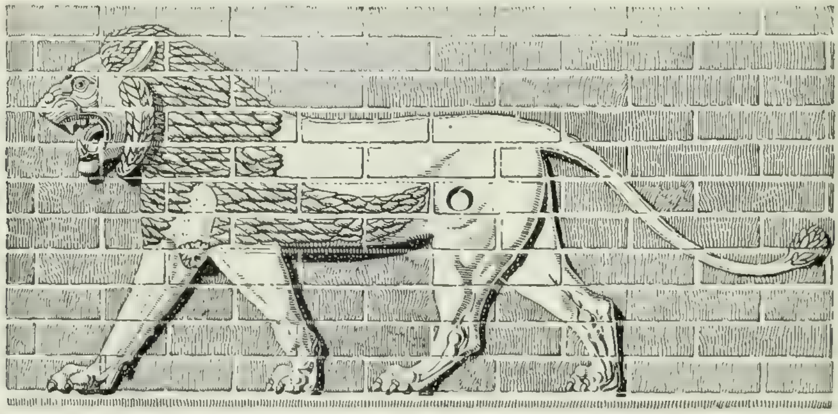


FIG. 115. IVORY COMB MADE BY PHŒNICIAN CRAFTSMEN AND DECORATED BY THEM WITH A LION DRAWN FROM ASSYRIAN SOURCES. The lion in gorgeously colored glazed brick was one of a line decorating the wall on both sides of a festival avenue of Nebuchadnezzar at Babylon. It was drawn by the Babylonian architects from such decorations in the Assyrian palaces (*e.g.*, Fig. 110).

FIG. 116. PHŒNICIAN SHIPS LANDING AT AN EGYPTIAN MARKET PLACE IN THE 15TH CENTURY B.C. (After Daressy.) The model of the Phœnician craft, with high bow and stern, shows that the Phœnicians built them in imitation of the earliest Egyptian sea-going ships (Fig. 84). The Phœnician merchants, clearly marked by their foreign costume, may be seen trafficking in the Egyptian bazaars. It was here that they learned the arts and crafts and the decorative motives which they then so freely introduced in their home ports, and transmitted throughout the Mediterranean, and also as far east as Assyria and Babylonia. The scene is taken from a wall-painting in an Egyptian tomb at Thebes in Upper Egypt.

ency to attribute too great importance to the cultural activities of the Phœnicians in the eastern Mediterranean, there has been a natural reaction; but it has gone much too far, and has overlooked new and important evidence like the painting of the Phœnician ships in Fig. 116. Here the Phœnicians are shown trafficking in the Egyptian bazaars, whence they drew the processes of industrial art, as well as its decorative motives. Similarly, unfinished work in ivory has been found in Assyria, still bearing the Phœnician workman's scribbled notes. As practisers and distributors of borrowed Oriental arts throughout a large area in Western Asia, and very widely in the Mediterranean world, the Phœnicians played an imposing rôle in the early centuries of the last millennium before the Christian Era. Phœnician merchandise like the ivory comb of Fig. 115 was common as far west as the Spanish Peninsula, where such things are found in early burials.

Dr. L. O. Howard,
President of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE

THE ST. LOUIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE seventy-second meeting of the American Association for the Advancement of Science and the affiliated national scientific societies, held in St. Louis from December 29 to January 3, was attended by about 1,200 scientific men. In view of the fact that several important affiliated societies were meeting elsewhere, this attendance must be regarded as satisfactory and it is certain that the scientific sessions and the various addresses, lectures, conferences and other features of the program were of great interest and importance. Thus the large lecture room used by the physicists was crowded and the dinner of the botanists was attended by about 200.

The formal opening took place in the auditorium of the Soldan High School on Monday evening, December 29, Chancellor Hall, of Washington University, delivering the address of welcome. President Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, responded fittingly, after which he introduced the retiring president, Professor John M. Coulter, who delivered the address on "The Evolution of Botanical Research," which was printed in the issue of *Science* for January 2. At the conclusion of this address the revised constitution was read and unanimously adopted.

Among the measures adopted by the council were the following:

That the American Meteorological Society and the Southern Educational Society, be admitted as affiliated societies. The council further declared itself as looking with favor on the affiliation of any national society which is interested primarily in scientific research.

That there be authorized the organization of members of the association in New Mexico, all or part of Texas and such other territory as may seem advisable into a Southwestern Division of the American Association for the Advancement of Science.

That arrangements for closer affiliation be authorized between the association and the academies of science of the Central States.

That the general adoption of the metric system by national and state governments be approved.

That the association will look with favor on any plan approved by the men of science in the country for the encouragement of research in engineering under the auspices of the government.

That the president be authorized to appoint a committee on international auxiliary languages to cooperate with a corresponding committee of the International Research Council.

That the American Association for the Advancement of Science will be pleased to cooperate with the National Physical Education Service in promoting physical education.

That sectional officers avoid placing on their programs papers relating to acute political questions on which public opinion is divided.

That approval be given to measures under consideration with the Carnegie Endowment for International Peace to enable the British, French and Italian equivalents of the American Association for the Advancement of Science to send delegates to the meeting to be held a year hence in Chicago.

That the sum of $4,500 be made available to the committee as grants for the ensuing year.

In accordance with the provision of the new constitution which calls for an executive committee of eight elected members to replace the old committee on policy the following were elected: J. McK. Cattell, H. L. Fairchild, Simon Flexner, W. J. Humphreys, D. T. MacDougal, A. A. Noyes, Herbert Osborn, H. B. Ward.

SOME MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,
At the Entrance of the Soldan High School, Headquarters of the Association at St. Louis.

Dr. L. O. Howard, chief of the Bureau of Entomology and distinguished for his contributions to economic entomology, who has served the association as its permanent secretary for twenty-two years, was elected president of the association by unanimous vote. Dr. Howard had previously stated that in view of the great enlargement in the work of the Bureau of Entomology and the increasing responsibilities of the office of the permanent secretary of the association, he felt unable to continue to hold the two offices. The election of a permanent secretary was consequently referred to the executive committee with power and it is now announced that Dr. Burton E. Livingston, professor of plant physiology in the Johns Hopkins University, has been elected to the office. Dr. E. L. Nichols, who retired this year from the active work of the chair of physics at Cornell University, for some years chairman of the committee on policy of the association, was elected general secretary.

The meeting of the association next year will be held in Chicago and this will be one of larger convocation week meetings held at four-year intervals in Washington, New York and Chicago, in which all the affiliated societies are expected to cooperate. It will probably be the largest and most important meeting of scientific men hitherto held in this country or elsewhere.

THE DUES OF THE AMERICAN ASSOCIATION AND THE SALARIES OF SCIENTIFIC MEN

THE revised constitution of the American Association for the Advancement of Science, as presented at the Baltimore meeting, was adopted at St. Louis with only one substantial change—an increase of the annual dues to five dollars. This change had been recommended, after careful consideration, by the committee on policy and the council and was adopted by unanimous vote at the opening general session of the association. The increase in the dues only meets the general situation. All the expenses of the association have increased in some such proportion, except the salaries of the officers, and it would be unfair to them and a bad example to other institutions, to retain nominal salaries paid in depreciated dollars. This has been done in the case of teachers in many institutions of learning and for scientific men in the service of the government, while commensurate with the increased cost of living have been the increases in wages for many of the working classes, and of the earnings of most professional and business men.

Institutions of learning and the scientific bureaus of the government have suffered alarming losses from their staffs. At the present time many men of science are hesitating between loyalty to their institutions and research work, on the one hand, and duty to the their families and the attraction of new opportunities, on the other. In one government bureau three men are now holding open offers of twenty to thirty thousand dollars a year to see whether the Congress will increase their salaries to six or eight thousand.

If men are driven away from positions where they are using their ability and their training for the general good, and if those who remain are compelled to use time that should be devoted to research or teaching to earning money from outside sources, the future of science and with it the welfare of the nation will be jeopardized. A generation might pass before there would be recovery from the resulting demoralization. It would be indeed humiliating to conquer Germany in war

Sir William Osler,

Regius Professor of Medicine at the University of Oxford and Honorary Professor of Medicine at the Johns Hopkins University, by whose death at the age of seventy years, the Anglo-American world loses its good and great physician.

and then permit it to surpass us in the arts of peace.

It is certainly unfortunate that the American Association should be compelled to increase its dues, as measured in dollars, at a time when all costs are advancing to such an extent that those living on fixed salaries find it extremely difficult to make both ends meet. It would, however, be a still more serious misfortune to permit the work of the association and its publications to be crippled. These are important factors in the advancement of science and in impressing on the general public the place of science in modern civilization and the need of maintaining research work for the national welfare.

The meetings of the association and the publications going to its members and read by a wide public are forces making for appreciation of the value of science to society and the need of giving adequate support to scientific research and to scientific men. Each member of the association contributes to this end and does his part to improve the situation for others as well as for himself. It is consequently to be hoped that no one will permit his membership to lapse on account of the necessary increase in nominal dues, but, on the contrary, that every member use all possible efforts to increase the membership of the association and to promote its influence and its usefulness.

GRANTS FOR RESEARCH OF THE AMERICAN ASSOCIATION

At the St. Louis meeting of the association, the council assigned the sum of $4,500 to be expended by the Committee on Grants for Research during the year 1920. The members of the committee for the current year are: Henry Crew, chairman; W. B. Cannon, R. T. Chamberlin, G. N. Lewis, George T. Moore, G. H. Parker, Robert M. Yerkes, and Joel Stebbins, secretary.

The committee will hold a meeting in Washington in the month of April, when the distribution of the grants will be made. Applications for grants may be made under the general rules given below, which were adopted in 1917; but the committee especially invites suggestions from scientific men who may happen to know of cases where young or poorly supported investigators would be greatly helped by small grants.

1. Applications for grants may be made to the member of the committee representing the science in which the work falls or to the chairman or secretary of the committee. The committee will not depend upon applications, but will make inquiry as to the way in which research funds can be best expended to promote the advancement of science. In such inquiry the committee hopes to have the cooperation of scientific men and especially of the sectional committees of the association.

2. The committee will meet at the time of the annual meeting of the association or on the call of the chairman. Business may be transacted and grants may be made by correspondence. In such cases the rules of procedure formulated by the late Professor Pickering and printed in the issue of *Science* for May 23, 1913, will be followed.

3. Grants may be made to residents of any country, but preference will be given to residents of America.

4. Grants of sums of $500 or less are favored, but larger appropriations may be made. In some cases appropriations may be guaranteed for several years in advance.

5. Grants, as a rule, will be made for work which could not be done or would be very difficult to do without the grant. A grant will not ordinarily be made to defray living expenses.

6. The committee will not undertake to supervise in any way the work done by those who receive the grants. Unless otherwise provided, any apparatus or materials purchased will be the property of the individual receiving the grant.

7. No restriction is made as to publication, but the recipient of the grant should in the publication of his work acknowledge the aid given by the fund.

8. The recipient of the grant is expected to make to the secretary of the

committee a report in December of each year while the work is in progress and a final report when the work is accomplished. Each report should be accompanied by a financial statement of expenditures, with vouchers for the larger items when these can be supplied without difficulty.

9. The purposes for which grants are made and the grounds for making them will be published.

SCIENTIFIC ITEMS

WE record with regret the death of Richard C. MacLaurin, president of the Massachusetts Institute of Technology, previously professor of mathematics in the University of New Zealand and of mathematical physics in Columbia University, and of George Macloskie, professor emeritus of biology in Princeton University.

OFFICIAL notice has been issued by the French Academy of Sciences of the award of the Bordin prize in mathematics to Dr. S. Lefschetz, assistant professor of mathematics in the University of Kansas, and of the Lalande prize in astronomy to Dr. V. M. Slipher, director of the Lowell Observatory at Flagstaff.—Dr. Jacques Loeb, of the Rockefeller Institute for Medical Research, Dr. Robert Andrews Millikan, of the University of Chicago, Dr. Arthur Gordon Webster, of Clark University, and Dr. W. W. Campbell, of Lick Observatory, have been elected honorary members of the Royal Institution of Great Britain and Ireland.

AT the dinner of the alumni of the Massachusetts Institute of Technology, held in Cambridge on January 10, it was announced that the endowment fund of four million dollars had been obtained by the alumni, thus securing the gift of an equal sum from the hitherto anonymous "Mr. Smith." It was revealed that "Mr. Smith," who has now given eleven million dollars to the Massachusetts Institute of Technology, is Mr. George Eastman, president of the Eastman Kodak Company.

THE SCIENTIFIC MONTHLY

MARCH, 1920

SPACE, TIME, AND GRAVITATION[1]

By Professor EDWIN B. WILSON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1. *Unrest in Physical Science.*—What you ask me to perform in presenting to you some discussion of the new conception of the categories of space and time suggested by Einstein's treatment of universal gravitation is a task that I accept reluctantly, even among friends and philosophers, because the matter is so new that an adequate judgment can no more be given to-day than a satisfactory judgment upon Maxwell's theory, whether in its philosophical or its physical significances, could have been given in the early days when he was forming it in his memoirs and before the appearance of his great treatise.

There is moreover, to-day, in the physical world a general unrest, little realized by non-physicists, and quite unlike the condition, I believe, existing fifty years ago. This unrest leads physicists to alternate, according to their temper, between a despair of ever settling the physical bases of the many new facts which experiment is thrusting upon them and a desperate grasping at any theoretical straw that offers even a feeble chance of support in the flood. In this generally febrile condition of our science it is particularly unsafe to draw philosophical conclusions.

When I read books or essays on philosophy that which impresses me most, next to their appearance of getting nowhere, is their apparent attempt to get universal judgments. I realize that much of this impression is probably due to a misconception on my part of the technical terms employed by philosophers. Such words and phrases as "Absolute," "original," "ultimate

[1] Read before the Royce Club, Boston, January 18, 1920. The first address to the Club, by its Founder, Professor Josiah Royce, appeared in *Science*, 39, April 17, 1914, pp. 551-566.

ground," "the eternal and immutable," "final causes," "first causes" and "comprehensive view of the universe as a whole" are quite unintelligible to me, although the last which contains "comprehensive," "universe," and "as a whole" seems on its face to be so far emphatic of something that I might reasonably expect to have a precise idea of what that something may be. To me this sort of phrase represents merely emotional aspiration.[2]

I say this in no spirit of contumely; for I shall probably use to-night many technical terms of but poor intelligibility to others—try as I shall to avoid them—and, besides, I suppose that next to the philosopher nobody so insistently tries to reach the "ultimate" as the theoretical physicist!

2. *The Dynamical View of Nature.*—I have spoken of the scientific unrest. The world seems to run in waves of excitement and of hum-drum, of discovery and of codification.

Two hundred years ago Newton set up the fundamental laws of kinetics and of gravitation. Little by little the major part of accurately known Nature came under the régime of these laws. A hundred years ago Laplace had shown the marvelous accuracy with which astronomical observations could be accounted for, and when Ampère and other continental workers came to develop the theory of electric and magnetic phenomena they followed the astronomical model. Stokes and Kelvin were students of dynamics and exponents of the dynamical explanation of Nature.

There was a time some fifty years ago when there was in the minds of many a belief that a dynamical account of the world at large was clearly foreshadowed. Maxwell, to be sure, gave up action at a distance; but, trained as he was in the English school, his point of view was largely dynamical—the dynamics of media, of the special medium known as the ether. He tried, and Kelvin long continued to try, to construct a mechanical model of the ether. There were bizarre theories of matter on a hydrodynamical basis—the atom founded on the persistence of vortices in perfect fluids, the atom built upon the theory of sinks and sources, and finally, not so long since, the general structure raised by Reynolds on the basis of a granular ether.

So happily did phenomena fit into the dynamical theory of

[2] May it be that some philosophers mistake emphasis for precision and description for definition? In times past mathematicians have used terms like "infinite," "infinity," "infinitesimal," "sum of a series," "differential," "imaginary," without sufficient precision in definition with resulting inconclusiveness of proof, fallibility of analysis, and bitter polemic even though confining themselves to much simpler questions than philosophers treat.

Maxwell and so near were we to a satisfactory material basis for the all-pervading medium that not a few of our ablest physicists two or three decades ago felt that we had already entered the hum-drum period of physics where the chief contributions were bound to be merely the more careful determination of physical constants—we were entering upon the reign of the "next significant figure." That there was need for this emphasis on accurate measurement will be granted by all who realize the pitifully inaccurate condition of electrical measurements, the large degree of indetermination in our standard electrical units, which then existed.

3. *The Flood of New Phenomena.*—As a prediction, however, of the future of physical science, the hum-drum forecast was bad. Perhaps the naturalist is too wise to hazard a guess that the future of his science is largely routine. But the outlook of some physicists in the middle nineties was not unlike that of the classifying naturalist who should hold that the thing best worth while was to get some money and some quinine and go in search of a new gnat in South America or a novel Nymphæa in Africa—quite blissfully ignorant of the great new realms of biology that would be opened by Mendel.

In the last twenty-five years we have learned that the atom is not indivisible, but consists of small charged particles or electrons. The physicist likes to have these particles in circular motion; the chemist wants them at rest except for oscillations about a position of equilibrium. We have learned about X-rays—some things about them—and through them we are learning much about many things. We have learned of radioactivity and the self-transmutation of certain elements. We have learned that radiant energy, at least in some of its manifestations, seems to possess a discrete or discontinuous structure, this leading to the perplexities of the quantum theory—perplexities not of physics alone but of mathematics and probability as well. Here is cause enough for unrest.

It may be that to give a satisfactory treatment of quanta we shall have recourse to a belief that space or time or both are themselves discontinuous and that their seeming continuity is but a statistical affair like the continuity of a fluid or solid. There is apparently a long-period oscillation in physics between the continuous and the discontinuous, and there is no reason why in some of its excursions the pendulum should not reach space and time.

4. *The Results of Careful Experiment.*—It is not only the great new things we have learned that trouble us; refinement of

measurement is itself a two-edged sword. Our physical laws are designed to correlate our observations. The correlation may remain good while our measurements are good only to three significant figures and become impossibly bad when we can determine five or six figures.

It has been known for some time that the perihelion of Mercury advances 42″ per century, and Newton's law of gravitation has given no wholly satisfactory account of this advance; there are also some slight unexpected secular variations in the moon's motion—enough perhaps to be visible to the naked eye after some thousand years. So either Newton's law is not perfect or there must be unknown masses, of relatively small amount, circulating in the solar system.

Turning to another branch of physics we have the exceedingly accurate experiment of Michelson and Morley wherein a ray of light is split, part being sent along the direction of the earth's motion to one mirror and back, part being sent an equal distance along the perpendicular direction and back. Now if the light travels in the ether with a velocity dependent only upon the elastic or quasi-elastic properties of the ether, the light going in the direction of the earth's motion and back will, owing to the motion of the mirror, travel a trifle farther than that going in the perpendicular direction. The difference in path amounts under favorable circumstances to about one half of one millionth of one per cent. of the path. This is not much, to be sure, but it should show very plainly in such accurate work as is done in interferometry, and it does not show.

One possible explanation would be that the earth drags the ether with it just as it drags its atmosphere; but there arise serious difficulties when this suggestion is pursued. Another explanation might be that there is a shortening of matter in the direction of motion—and this has been followed up by Lorentz.

5. *The Electric Theory of Matter.*—The suggestion of shortening is not unnatural on the electromagnetic view of matter. When a charged sphere moves, the lines of force, instead of remaining isotropically divergent from the sphere, crowd up toward the equatorial plane perpendicular to the direction of motion and leave the poles of the sphere in the direction of motion with a smaller superficial charge. The tendency of the sphere is to shorten in the direction of motion. Now if all matter is made up of electrons, and if the electrons themselves tend to shorten in the direction of motion, with the attendant alterations in their field of force, it is not unreasonable to sup-

pose that all matter suffers the same shortening when moving through the ether.

The shortening is greater as the velocity of motion is greater. For the earth which moves only 30 km. per sec. in its orbit about the sun, the shortening is only a few inches in 8,000 miles. For an electron which may move at 9 tenths the velocity of light, the shortening is more than half, and if an electron should move at 99 hundredths of the velocity of light, its diameter in the direction of motion would, on this hypothesis, be only one seventh its original amount so that the electron would appear disc-like instead of spherical.

There is another effect of the shortening which is calculable, and that is the gain in electrical energy, and the gain in inertia. A flattened electron when accelerated in the line of its motion tends to become flatter; part of the work done by the applied force must go into crowding the lines of force toward the equatorial plane and hence only part remains over to accelerate the mass. The result is that for a given force the acceleration is less than if the flattening did not take place, or to put it differently, the mass or inertia appears greater. Thus the electron has conceivably two masses or inertias: one due to its mechanical mass, the other to its electrical inertia, and the latter part varies with the velocity in a perfectly definite way. When the experiment of determining the inertia of the moving electron is tried, it is found that apparently all the inertia is that of electrical origin with none left over for ordinary mechanical inertia.

This discovery suggested very strongly that the day for a mechanical explanation of nature has definitely passed and that henceforth, at least for the immediate future, the attempt should be made to give an electrical foundation to mechanics and to all natural phenomena.[3] J. J. Thomson, as a matter of fact, long previously had shown theoretically that a charged material sphere has additional inertia by virtue of its charge, but for ordinary spheres the amount of added electrical inertia is inconsiderable compared with the mass of the material. It was only when the infinitesimal and relatively enormously charged electron became available for direct experimental work that the

[3] The attempt to give a unitary basis to the whole of physical theory has an irresistible fascination and physical theory advances by the strife between this monadic ideal and the ever-growing volume of physical fact. It is like the contest between armor plate and the armor-piercing projectile. Sometimes one appears to be winning, sometimes the other; on the whole, it is a draw. What we have at any time is not one physical theory, but a congeries of theories. See a note by G. W. Stewart, *Science*, 51, 1920, pp. 95–86.

amount of the electrical inertia and the law of its increase with velocity could be determined.

6. *The Old Relativity.*—This idea of shortening in the direction of motion was physically satisfying, but not so philosophically. Space and time are not absolute. Every point of space is just like every other and the only position known or knowable on the basis of Euclidean geometry is relative position. There has been since Newton's time, and before, a natural belief in a principle of relativity. Neither absolute position nor absolute uniform velocity are determinable.

The laws of motion, when resolved far enough, show this. We have to do with accelerations of particles and the value of the acceleration of a point is unchanged when the position of the point is specified by reference to any set of axes whether at rest or moving uniformly parallel to themselves. (The acceleration is affected by a rotation of the axes.) Moreover, the acceleration is not altered by any choice of an initial instant from which to measure time. Finally, as the action and reaction between two particles lie in the line joining them and are supposed to depend only on the distance between the particles, the forces which enter into the equations are expressed in terms of quantities (*i. e.*, distances) which are independent of the choice of axes. Thus arises a belief in relativity.

It is true that the equations of motion for definite bodies moving under the definite conditions inherent in some particular problem may not be analyzed down far enough to reach the simple invariant form indicated. For example, a resistance may be taken as a function of a velocity—a statistical form of expression which gives the gross resultant action of all the myriads of air particles on a bullet. Yet we should believe that if each gaseous molecule were considered, the forces would be representable as functions of the distance; and indeed even when we insert a velocity into the equations of motion it is always regarded as a relative velocity.

We have then in ordinary mechanics a full-fledged, if sometimes quietly ignored, principle of relativity. All that can be treated or known is relative motion when translation is concerned. Newton noticed the difference arising in the case of rotation, which of course involves acceleration even when the angular velocity is uniform.

7. *The Absolute Ether.*—Return now to the ether. This is regarded as a medium filling all space and fixed except for its tremors which show us light. The ether furnishes an absolute

material space, so to speak—and motion becomes conceptually motion relative to the ether. But as no effect of motion of the ether itself (except its tremors about its mean position) has been detected, there is no reason why the ether in its mean position should not be regarded as an absolute and motion relative to it as absolute motion. If this be so, those who desire "absolutes" have their innings.

Here is where the famous Michelson-Morley experiment comes in. If the ether is at rest, pervading all matter but not dragged with it, an interference experiment should clearly show the drift of the earth through the ether—not only the drift due to the motion about the sun, but the drift to the motion of the solar system towards its apex. And the result of the experiment was negative. So also were the results of other experiments which by other means should detect the drift. These negative results may all be explained by shrinkage in the line of motion.

Why then should this effective physical explanation be philosophically unsatisfying? Because. Just because. This is "a woman's reason." It is a good one. I know of none more convincing. Perhaps part of the dissatisfaction is due to our long-continued belief in relativity fortified by a growing distrust of any absolute background which refuses in any way to disclose itself as in motion relative to us.

If lengths in the direction of motion shorten, our measuring instruments shorten so as exactly to counterbalance the abbreviation of the thing measured. Why then should we believe in the shortening at all? May it not be that the shortening itself is only relative? That is, if A and B, being in relative motion, observe a distance PQ with meter sticks which are identical when at rest, A and B will differ on the measure of PQ by perhaps one half of one millionth of one per cent.; but why should B claim that it is A who is in motion and who has not corrected for his shortening—why may not A equally well claim that it is B who is in motion and has not corrected for his shortening? And if a third party comes in as referee, and makes a finding different from both because neither is at rest relative to him, what then?

8. *The New Relativity, Space and Time.*—This sort of question did not bother many until Einstein raised it and started out to solve it by boldly affirming that we must construct our space and time concepts in such a way as to avoid these discrepancies and give us a real relativity consonant with physical fact and

independent of the opinions of different observers as to who is and who is not in motion.

A fundamental postulate of his theory is that the velocity of light $c = 3 \times 10^{10}$ cm./sec. appears the same to all observers. This means that velocities do not add according to the ordinary law. Any velocity compounded with the velocity of light gives the velocity of light—no more, no less. Two velocities in the same direction do not compound into the sum of those velocities but into that sum diminished by a small amount.[4] The geometry of velocities, so to speak, is non-Euclidean.

A still more striking revision of ideas is necessary relative to space and time, because these two conceptions become necessarily interrelated, whereas in Newtonian relativity they were independent. Two observers with relative motion measure space differently; they measure time differently; they do not even have the same space and the same time, because the time *or* space measure of either depends on the space *and* time measure of the other, in such a way that they do not agree even as to the simultaneity or not of events happening at different positions—nor do they agree as to the identity or non-identity in position of two events happening at different times.

A fusion of the time and space concepts into a single time-and-space idea is necessary to bring simplicity out of the confusion. What this does to the metaphysician who is interested in settling "what it is that we know and how it is that we know it" is more than I can say. Such discussions as I have read of the categories of space and time would seem to have very little left as an ultimate residuum.

9. *Knowledge of Nature.*—In an article on metaphysics[5] by a philosopher with obvious sympathetic leanings toward Aristotelian methods and an Aristotelian realism I find this qualification in summary: "Aristotle could not know enough, physically, about Nature to understand its matter, or its motions, or its forces; and consequently he fell into the error of supposing, etc." Now relatively speaking there is a good chance that Aristotle in his day did know more, physically, about Nature than a philosopher of to-day can know. There was much less known about Nature then and the sort of thing known was much simpler, and Aristotle was a profound student of Nature with

[4] If B's velocity appears to A as u and C's velocity appears to B as v, then the composition of the velocities is by definition that velocity which C appears to have to A. In ordinary mechanics this is $u + v$, in relativist mechanics it is not.

[5] See "Metaphysics," Encyc. Brit., 11th ed., Vol. XVIII.

the best resources of his time largely at his disposal. Aristotle probably knew Nature better than a physicist to-day knows physics or a chemist chemistry.

Here again I must state that I am not trying to be contumacious toward the philosophers in this group. I appreciate thoroughly that our Founder tried to collect into this aggregation students of many a field for the very purpose of pooling our philosophical interests and our scientific information of mutual philosophic import. I wish to emphasize merely this: That nobody at any time can know enough about Nature to understand its matter, or its motions, or its forces and that consequently everybody will fall into error if he goes to supposing this or that or anything else which is of the sort that later discoveries may upset.

Certainly it is difficult to ascertain what it is that can not by any future development be upset—and as I understand them this it is, and this alone, that interests many philosophers. With Einstein's relativity of 1905 space and time as separate things disappeared into the space-time fusion. Does everybody believe this? By no means. The great majority are still either indifferent to it, because it does not immediately affect their work, or set against it because it is not "physical" but "philosophical."

10. *Force, Real or Fictitious.*—Query: When is a force not a force? Answer: When it is a "reversed effective force." To amplify this conundrum I will recall to your mind the general principle of d'Alembert to the effect that: The impressed forces acting on a body taken with the reversed effective forces form a system in equilibrium. This amounts really to transposing the terms in the equation $Ma = F$ so that $0 = F - Ma$. The force F is the impressed force, the force $-Ma$, the negative of the mass times the acceleration, is by definition the reversed effective force.

This principle is of great convenience. It enables the engineer to treat a problem of motion in a curve by the introduction of the fictitious "centrifugal force," which is of course the reversed effective force—not a true physical force (the physical force is centripetal). By this fiction the force-analysis relative to the body in curvilinear motion is reduced to a simple static diagram.

Suppose we are in a uniformly moving train and cannot look out. Thanks to the principle of relativity, all goes nicely according to the Newtonian laws, until we strike a curve. Then everything has an outward acceleration—apparently. Really there is no outward acceleration. The bodies are merely trying to maintain themselves in uniform motion in a straight line—at least this is the interpretation we have come to put on the phenomenon since Newton's time.

Now as a matter of fact we are on a very smoothly running train all our life; but the earth turns with so small an angular velocity that it has been only in recent times that it has become convenient, and consequently real, among scientists, to regard the world as turning. And only in still more recent times have refined experiments such as those with Foucault's pendulum and with gyrostats shown us before our very eyes this rotation of our frame of reference. We may regard the earth as non-rotating if we choose, but the introduction of "centrifugal" and "Coriolis" forces which are fictitious reversed effective forces. Indeed, for the solution of such problems the introduction of these fictitious forces is generally more convenient than to use a fixed frame of reference, even though we know better than to adopt as a philosophy a non-rotating earth and as physically existing the fictitious forces in question. We are very wise about things we have long since come to believe.

But just suppose that somebody tells us that the force of gravity is physically non-existing quite as much as the centrifugal or Coriolis force, and that the reason we think that gravity is real is essentially the same that leads the untutored mind to believe there is a physical force acting to move objects to one side when a train goes around a curve—namely, an unhappily ignorant view of Nature. This is what Einstein asserts.

11. *The Space-Time Path.*—He goes further and maintains that instead of every particle of matter attracting every other particle according to the Newtonian law, each particle goes its way on the shortest or straightest path possible, when both time and space are considered in a single space-time manifold.

That the path of the planets is really nearly straight may easily be seen. In the motion about the sun the earth turns through about 1 degree per day and departs from its rectilinear motion by 22,000 kilometers in 2,600,000 when space alone is considered. But, using the velocity of light as a standard, 1 second of time is equal to 300,000 kilometers of distance. Hence in a day, which is 86,400 seconds, the advance in time is the equivalent of some 26 billion kilometers, while the motion in the path is only one ten thousandth as much and the motion across the path is only 22,000 kilometers or less than one millionth as much.

In the space path we have a departure per day from rectilinear motion of about one part in a hundred; on the space-time path the departure from rectilinear motion (motion with uniform velocity) is about one part in a million, which represents a much smaller curvature—the path is nearly straight.

This may all be made clearer by regarding the space-time path as constructed in the following manner. Draw from the sun perpendicular to the plane of the earth's orbit a line which shall represent the time-axis and disregard the third spatial dimension. Now for each km. that the earth moves around in its orbit, it must be considered to move in time by 10,000 km. The path of the earth in space and time on this diagram is therefore a helix with an extremely steep pitch winding once per year about the cylinder standing in the earth's orbit but advancing ten thousand billion km. while "circulating" one billion km.

Such a helix departs very little from a generator (vertical element) of the cylinder and is nearly straight. Not much quantitative change in our space-time measurements, however great the qualitative change might be in our space-time concept, might make the space-time path a geodesic or shortest path in a curve space-time manifold. Einstein shows how to make the change.

The mathematics is complicated; it depends on the theory of quadratic differential forms which to me seems perhaps the most intricate branch of pure mathematics and is at all events one unfortunately little studied in America—or anywhere else except in Italy. Einstein himself stumbled many times before he succeeded, not without the aid of others, in making the change he desired, but his progress toward his objective was relentless and must have required both a keen imagination and an iron will.

12. *"Curved" Space.*—A word about curved space. This is a difficult concept to non-mathematicians. All will admit that a two-dimensional spherical surface is curved in three dimensions. The difficulty is in seeing how a person limited to two dimensions in his motions and without any imagination of a third dimension could conclude from his observations on the spherical surface that the surface was not flat but curved. Or how we, limited to three dimensions, could by observations in three dimensions decide that our space was curved. Or, still worse, how we, limited to four dimensions of space and time, could by observation determine that our space-time manifold was curved.

Let us consider the case of the spherical surface and compare it with that of the plane. Suppose the plane inhabitant selects an origin O and a line OL issuing from it and specifies the portion of a point P by the distance OP of P from O and the angle POL giving the "bearing" of P relative to OL (polar coordinates). Then he will find that the distance between two nearby radial lines OP and OP' at equal distances $OP = s$ from the origin O will be the product of $OP = s$ and the infinitesimal angle POP', and that the length of the circle about O as center and with OP as radius is $2\pi OP = 2\pi s$.

Now the inhabitant of the sphere will find a very different result by the similar procedure. He selects his origin O and line of zero "bearing" OL. (This line will from our external point of view be a great circle, but from his point of view a straight line or geodesic, because its curvature being wholly normal to his space is not directly perceptible.) He will find the infinitesimal distance at any point between two nearby lines OP and OP' not as OP times the angle POP' but as this product multiplied by $\sin s/a \div s/a$ and the whole periphery of the circle equidistant from O not as $2\pi OP$ but as $2\pi OP$ multiplied by the same factor, where a is some constant.

The difference between the results

$$2\pi s \quad \text{and} \quad 2\pi s \times (\sin s/a \div s/a)$$

for the perimeter of circles of radius $OP = s$ is surely significant of something. You may call it significant of the curvature of the sphere even though you attach no other significance to the word curvature. It is indeed probable that the use of the word curvature here is attributable to our three-dimensional view of the sphere.

When we work in our flat three dimensions we find the area of a spherical surface of radius OP to be $4\pi \overline{OP}^2$; if we should find it to be something else such as $4\pi \overline{OP}^2 \times (\sin s/a \div s/a)^2$ we should attribute this to some property of our space and seek to interpret the constant a relative to the space. We may or may not speak of our space as curved but we do at least recognize that the formula for the area of a sphere of radius OP is not directly proportional to the square of OP when OP is large though it is when OP is infinitesimal relative to the constant a.

In the Newtonian relativity space was flat and independent of time; in the Einstein relativity of 1905 space and time had to be considered together but the manifold thus obtained was still flat and no special account was taken of gravitation, the theory was essentially electromagnetic in the sense that it was fitted to the electrical conception of Nature; in the Einstein new relativity space and time must still be considered together but the space-time manifold has become curved and the curvature has been so adjusted that the major effects of gravitation, as ordinarily considered, have been accounted for by the curvature of the space-time manifold so that every particle of matter pursues a geodesic or straightest path in the four-dimensional manifold.

The further explanation of detail is complicated by the fact that there are different sorts of curvature. Consider again the spherical surface. There is one curvature, called the mean curvature, which is estimated relative to the radius and is exactly equal to the reciprocal of the radius, $1/a$. There is another curvature, called the total curvature, which is estimated relative to the square of the radius or to the area and is taken as equal to the reciprocal of the square of the radius, $1/a^2$. On the sphere both curvatures are constant; in the plane both are zero. On a cylindrical surface of radius a, the mean curvature is $1/2a$, the total curvature is zero, both are constant.

An interesting class of surfaces is that formed by soap films stretched across various forms of wire. The film has to stick to the peripheral wire, but is otherwise free to contract under the influence of the surface tension of the film. The result is that the film shrinks into the form of the surface of least area, the so-called minimal surface, which can span the periphery. Such surfaces have their mean curvature constantly equal to zero. They are saddle shaped with as much positive curvature in one normal section as there is negative curvature in the perpendicular section; the total curvature of such surfaces is negative and variable, being zero at the periphery where the film is attached to a segment of straight wire. In stepping up to three dimensions there are curvatures expressible as reciprocals of lengths, or of areas, or of volumes, and of these the first two are types of mean curvature, the last of total curvature.

Generalizations to four dimensions may be made. But when we have to deal with gravitational effects of matter considered to be at rest, as is the case with the dynamics of the solar system so far as these are attributable to a sun regarded as at rest (and in abstraction from all perturbative effects) it has been shown by Levi-Civita that space and time may be separated (as is also the case in the 1905 relativity where observers agree as to what is at rest) so that phenomena pass in time and in space.

The three-dimensional space surrounding the central sun is, however, curved, but with zero mean curvature much as the soap film is curved but with no mean curvature. Within the mass of the sun the mean curvature is not zero, but is intimately connected with the density of matter or of energy.[6] For Einstein's theory is one of energetics.

13. *Energy and Mass.*—We have stated the theory chiefly with relation to its modification of our space and time concepts and with but little account of its underlying physics or philosophy except in so far as concerns the early relativity of 1905. It is necessary to return to the physics and philosophy of Einstein between 1905 and 1915.

It was seen that the mass or inertia of any electron was wholly electrical. Now mass according to our older concepts has two properties—inertia and weight, for both of which Newton set up the quantitative formulation. Does the electron weigh? Is the electrical inertia, which is proportional to the electrical energy, of the electron subject to the law of gravitation? If matter is wholly electrical, the simplest hypothesis is that the electron does weigh.

A beam of light represents energy; according to Maxwell it represents also momentum which should be disclosed as the pressure of light when the light is either absorbed or reflected. The pressure has been measured. Light, therefore, has the two principal characteristics of moving matter, energy and momentum, why should it not have the other two, inertia and gravitation?

The physicist generalizes on very slight evidence if his fancy, his esthetic sense, is sufficiently insistent. We have come to believe[7] that every quantity of energy, of whatever sort, represents just so much mass, that every amount of mass represents just so much energy of some sort, and that every bit of energy attracts every other bit of energy just as much as every particle of matter attracts every other particle—which on the new theory is really not at all, so that we must state it other-

[6] That Einstein's gravitational theory makes it *necessary* for us to think of our space-time manifold as curved I would not say. The non-Euclidean plane geometry of Lobatchevsky may be developed without specific reference to the curvature of the Lobatchevskian plane; or it may be treated as the geometry on a surface of constant negative total curvature such as the pseudosphere; or, by the aid of the Cayleyan system of measurement, as a type of geometry inside an ellipse or circle in the Euclidean flat plane. See "Geometry," Encyc. Brit., 11th ed., Vol. XI.

[7] I am here trying merely to state Einstein's ideas as I understand them, as throughout this paper, without wishing to give the impression that all of these ideas are yet universally accepted or even certain to become widely accepted. The theory is still young and may succumb to infant diseases instead of to general disintegration after a ripe old age.

wise, namely, that every particle of energy puts its appropriate crimp into our space-time manifold. Or to give a better phrasing, departures of our space-time manifold from flatness are correlated definitely with what we otherwise term energy.

The numerical relation between mass in grams and energy in ergs is this: The mass is the energy divided by the square of the velocity of light. Thus one gram of matter represents 9×10^{20} ergs or over 21 billion calories. Conversely, a hot brick is heavier than a cold one—it has more mass by the amount of heat added if measured in ergs and divided by 9×10^{20}. To heat 1 kg. of water 100° C. requires about 4.2×10^{12} ergs; the increase in mass or weight is therefore only about 5 millionths of a milligram. If there were any way of making even a small part of the energy latent in matter available, our supply of useful energy would be enormously increased. It may be that the sun is in a condition where such conversion is going on. Radioactive matter is in such a condition.

14. *Einsteinian Physics.*—But to return now to light regarded as suffering attraction because, being energy, it is mass. A simple calculation of the deviation of a ray of starlight passing close to the sun on its way to our eye shows that on the Newtonian theory the deviation would be 0.87″ and would fall off inversely as the distance of the periphelion from the center of the sun. (In the astronomical work of determining parallaxes, 0.87″ is a very large quantity, larger than any stellar parallax.) This was Einstein's first estimate. When he had formulated his complete theory, a new calculation showed that, on the curved space-time hypothesis, the deflection should be twice as much, namely, 1.75″.

The solar eclipse of last spring gave an opportunity to measure the deflection which was found to be in satisfactory accord with the new theory, not with the ordinary Newtonian. The report of these findings as presented at a recent meeting of the Royal Society was the occasion for the newspaper interest in the obsolescence of Newton.

Another fact that was really the cause of an early widespread interest in Einstein's work on the part of astronomers was that from his theory a calculation of the motion of Mercury showed an advance of the periphelion of 42″ per century, the amount that had so long defied satisfactory explanation.

A third consequence of the theory is that light originating near a great mass such as the sun should be of lower frequency than if originating near a small mass like the earth; the lines in the sun's spectrum when compared with laboratory standards should be shifted toward the red by a minute amount much as if the sun were traveling away from the earth.

This prediction has been subjected to a most searching experimental analysis at Mt. Wilson and remains unverified, though if the effect existed, it ought to have been found. The phenomenon may ultimately be found or its absence satisfactorily explained. On the other hand the deflection of rays of light by the sun, as solar eclipses are again searched, may be found to be absent or may be attributable to refraction in an extremely tenuous solar upper atmosphere.

There are, moreover, some cosmographical speculations by Einstein relative to the finiteness of our sidereal universe, and the distribution of matter in it, which I should mention if there were time. Cosmography, however, has become a large science in itself, in the last few years, with tolerably definite and highly interesting conclusions which should be treated in their entirety, and to this whole the present contributions of Einstein's theory are, of course, small.

15. *Einsteinian Philosophy.*[8]—Our interest here is primarily with the philosophical and there is one fundamental view of Einstein's which seems to have been his guiding star through his earlier and his later relativity. In 1905 he desired to construct a theory independent of the rest or state of uniform motion of any observer—certainly a philosophical ideal.

Later he introduced his "postulate of equivalence" wherein he states that from observations in a closed system (our railroad train) an observer should be unable to tell whether he were at rest in a gravitational field or in motion with a uniform acceleration. Thus not only can the isolated observer not determine his absolute motion (velocity), he can not tell how much of the force he feels may be due to attracting masses and how much of it to his own acceleration. This is a reasonable philosophic idea or physical assumption.

We all know that we feel lighter in an elevator moving with a downward acceleration whether this be in starting downward or in stopping toward the top of a rise. And we have all heard the more complicated conditions arising in flight, and the indetermination which arises thereunder, discussed by aviators when telling of flights in clouds.

One can see in the equivalence postulate the germ of the

[8] Reference should be made to *Science*, 51, Jan. 2, 1920, pp. 8–10, where Einstein gives his own statement. See also "Relativity Theories in Physics" by R. C. Tolman in a forthcoming number of the *General Electric Review*, Schenectady.

idea that gravitation is a fictitious force, and the possibility that an observer by his own measurements would come to some space-time conception which in itself should cover the phenomena ordinarily attributed to gravitating masses.

Another proposition which guided Einstein was that the laws of nature, whatever they be, should be expressible in such a manner as to remain valid when any system whatsoever of time and space coordinates be used. This insistence on a general invariantive or covariantive statement of law is responsible for much of the mathematical difficulty in the formulation of the theory, but we have the author's testimony that it was of considerable heuristic value.

The relativity principle whether old or new (1905) regarding velocity and the equivalence postulate regarding gravitation and acceleration are types of a "philosophy of ignorance" such as is often met in the theory of probability, in the "principle of sufficient reason," in arguments from symmetry, etc. It does valiant service for the wise, but is a dangerous tool for the really ignorant.

This method in science may be called the philosophic if it be desired to have a phrase contrapuntal with the scientific method in philosophy[9] concerning which Mr. Hoernle spoke to us at our last meeting. The meaning of the adjective is, however, not positive but comparative and reaches out toward the superlative in either case only as the adjectives philosophic and scientific are conceived in their narrowest senses.[10]

16. *Man's Place in Nature.*—Man's place in physical Nature used to be central. His earth stood still and everything re-

[9] The method, roughly, of Russell and Whitehead. Undoubtedly life is too short to cast everything into a rigorous mould and much would be lost by an insistence on the method. In mathematics itself the extreme rigorous and logical method is not pursued except in restricted fields or when dangerously critical problems are attacked. But a well-trained mathematician or mathematical physicist must to-day have had some education in extreme rigorous analysis that he may come to know the pitfalls that are in the way of careless workers and avoid them. A similar training in the scientific method for its educational value should be required of students of philosophy; it saves time in the long run.

[10] Although Einstein's method has been called philosophical, one should not infer that Einstein is technically a philosopher or that philosophical technicians will agree as to the system of philosophy that is fortified by his conception of Nature. Mr. Hoernle has called my attention to some spirited correspondence between Whitehead and Walker in the *Nation* (London) for Nov. 15, 29 and Dec. 13, 27 (1919) wherein the former claims that Berkeley has been avenged and the Aristoteleans put to rout, while the latter finds that only now has Aristotle completely come into his own. Alas, poor Yorick!

volved around it and him, and his god or gods sat off where they were put and were pleased by his frankincense. And he saw everything he had made and behold, it was very good, and when he had thus done and been satisfied with the goodness thereof he rested,—upon his Carnegie pension, or otherwise.

How near to this point of view some metaphysical idealists may still be I do not venture to surmise. Certainly the perusal of some presentations of the more extreme idealism gives the scientist the impression that there have been those who would convert that reverent and realistic scientific lullaby

Twinkle, twinkle, little star;
How I wonder what you are
Up above the world so high
Like a diamond in the sky.

into some such blasphemous conceit as

Twinkle, twinkle, little star;
I know what you really are—
Just a greedy summer fly,
Creature of my inner eye.
Nibbling at that hunk of cheese
Half a mile beyond the trees.

Probably none of their ilk remain.

Man's place to-day in physical Nature is far from central. He should be decidedly humble. He knows infinitely little and what knowledge he has is for the most part either a partial understanding of discrete facts or a conventional correlation of different facts based not upon ultimate truth but upon the brief convenience of the leading minds of his time,—to the lesser minds the convenience of the leaders may be a serious inconvenience.

In Homeric times the earth was flat. A thousand years later it was round, first by philosophic or mystic fancy, then by indisputable proofs of Aristotle, measured with accuracy by Eratosthenes and charted by Ptolemy. For a thousand years under Christianity the earth was again flat, and no "good" man could think otherwise. Since a bare five hundred years the world has been round again, first for martyrs and then for all. Who shall say that it will not again become flat? Viewing history and the prehistoric record as a whole who dares predict that some barbarian horde, some incendiaries of libraries, some religious bigotry will never wipe out present knowledge, replacing it for long periods of time by some earlier doctrine that we now deem less convenient, untrue.

Aristarchus had a good heliocentric theory of the world;

why should Hipparchus have chosen the geocentric—the greater reversing the lesser scientist? Why should Ptolemy have continued the error? What seemingly sound scientific doctrines of to-day are the geocentric systems of Hipparchus and Ptolemy, overriding, reversing the saner positions of some humble Aristarchus of a generation ago who may yet wait centuries for vindication? May it be the luminiferous ether? Einstein is quoted as saying there is no ether. Is the early corpuscular optics to return, modified of course sufficiently to account for our present continuous optics, and shaped to cover our discontinuous optics of quanta? I do not know.

The absolute and the universal, though perhaps a guiding inspiration, remain mere emotional aspirations. Under the analysis of the last century even our logic broke down before the paradox of "the class of all classes," and however much we may push off this contradiction by finer analysis, I do not believe we shall be rid of it until we abandon such phrases as the class of all classes,—any more than the mathematician was rid of his difficulties with the simplest type of infinity until he insisted that this was no infinite except as an indefinitely increasing finite, so that the static infinite became the kinetic finite.

We are acquiring and discarding, learning and forgetting, and at any time there is nearly an equilibrium between import and outgo; for some centuries we gain, for others we decline with a fall far more swift and precipitous than the arduous climb.

Not the survey of the latest theories, nor estimates of the immediate future, nor yet the study of the past few centuries will suffice to ground a philosophy. Several millenniums are necessary. On the whole we seem to be getting on. At least we must have faith to carry on.

And so for a philosophy I turn back to the first of the metaphysicians whose doctrine, as I understand it, may be phrased in the words of the passing song, "We don't know where we're going, but we're on our way." Far better so than "All dressed up and nowhere to go"—yes, worse, left behind, in the majestic march of Nature and of man's living thought upon it.

THE NEED FOR A MORE SERIOUS EFFORT TO RESCUE A FEW FRAGMENTS OF VANISHING NATURE[1]

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IN these days of anxiety and suffering, when large populations are on the verge of starvation, and revolution threatens us within our own gates, it might not seem especially opportune to urge the claims of any movement not immediately concerned with the welfare and safety of mankind. This is perhaps particularly true of any proposal to render unavailable for human consumption considerable fragments of what we are wont to term our "natural resources." Indeed, the most plausible objection on the part of those who are engaged in the commercialistic exploitation of these resources, would be this one, that everything in the world must be made of some "use" to humanity. Such talk seems to breathe of the spirit of altruism, and it also harmonizes very well with the dominant utilitarianism of the day.

And so it comes about that most of the "conservation" which is being preached in these days is the conservation of our *resources,* of our coal and our lumber and our water-power and our fisheries and what not. Heaven knows that all these belated reforms are necessary enough. But there is another sort of conservation which has thus far received utterly inadequate attention. I refer to the conservation of nature—nature as a source of scientific knowledge and of the highest esthetic enjoyment of mankind.

Some of you will think at once of our National Parks and our National Forests, of our Audubon Societies and our game-laws, and will conclude that the needs which I speak of have already been sufficiently well provided for. I have little doubt that a large proportion of even that small minority who have any real interest in the preservation of nature and of wild life soothe themselves with this reflection that the existing agencies are quite adequate for the purpose.

We can not give too high praise to those individuals and

[1] Lecture delivered before the California Academy of Sciences, San Francisco, December 3, 1919.

organizations which have thus far succeeded in checking, however slightly, the destruction of our natural scenery and of the native fauna and flora of our continent. But it is utterly foolish to imagine that these slight beginnings are sufficient to avert a great and irreparable catastrophe.

I think that no harm can come from our endeavoring to indicate, in a general way, the sort of things which we should like to accomplish, had we the power. This, even though our aims, in some respects, may prove to be impossible of realization. There are two equally important lines of effort, prompted by two quite distinct motives. The first of these motives is the scientific one.

Biology is the science of life, of the totality of plants and animals which occupy or have occupied the face of our planet. One might readily conclude, however, that there are zoologists, and some of them occupying high positions, who would not be greatly disturbed if the entire natural fauna and flora of the earth, with a few specified exceptions, should be destroyed overnight. If we left them the various laboratory types which are dissected or sectioned in "Zoology 23," along with the fruit-fly and one or two domesticated mammals and birds, I am not sure but they would rest peacefully in the belief that all future needs of their science had been fully provided for. I can not speak with any such confidence for the botanists, but the fact that neither they nor the zoologists are making themselves heard from at all audibly in this matter, seems evidence of the comparative indifference of both groups of biologists to the worldwide assault upon living nature.

It would hardly seem necessary to justify to scientific readers the importance of saving from destruction the greatest possible number of living species of animals and plants, and of saving them, so far as possible, in their natural habitats and in their natural relations to one another. And this is not primarily in order that the ornithologist, the entomologist, and the rest, shall gratify their traditional passion for naming species. It is because some of the most important problems of biology are concerned with relationships, and can only be solved by comparisons. Comparative anatomy was to Darwin, as it is to us, one of the chief fields to which we must look for our evidences of organic evolution.

Another of these fields is that of geographic distribution. It is not only the broader questions involving the larger subdivisions of the animal kingdom—the orders, families and genera—which are of importance here. One of the most promising lines of attack upon the still unsolved problem of the "origin of species" is to be found in the study of our *incipient species, i. e.*, our "subspecies" or geographic races. If most of these are shortly to be exterminated, and many others to be displaced from their natural habitats, we shall have lost a highly important clue to the initial stages in the formation of species in nature.

Then, too, what shall we say of the modern science of ecology, which concerns itself with the totality of animal and plant life in particular regions, viewing these whole assemblages as being themselves organisms, having a definite cycle of development, like an individual animal or plant. It is significant that the ecologists, of all biologists, appear to be most active at present in the campaign for the preservation of natural conditions.

But aside from these broader considerations, can the laboratory biologist feel quite certain that even the "types" chosen for his class-work, or the "material" for his own researches will be eternally safe from depletion without any effort on his part. We have for some years been hearing of the difficulty of obtaining such classical objects of research as the sea urchin and some other organisms for the laboratories at Woods Hole. It would seem as if the biologist, like the hunter and the fisherman, had been seriously jeopardizing his own future supply of game.

The second great motive for the conservation of nature is that which, for a better name, we might call the esthetic one. I think, however, that this word, if employed in the present connection, would convey my meaning quite inadequately. For the love of nature includes vastly more than the appreciation of natural scenery. It includes that deep-rooted feeling of revolt—not yet quite dead in most of us—against the noise and distraction, the artificiality and sordidness, the contracted horizon and stifled individuality, which are dominating features of life in a great city. Now it may be that such a feeling of revolt may represent merely a passing phase in human development, indicative of incomplete adjustment to a really higher plane of existence. It may represent the welling up of atavistic, antisocial tendencies, which it is our duty to sternly repress. Perhaps the highly socialized man of the future will gather more inspiration from the mad crush of the home-bound subway crowd in New York City than he will from the solemn majesty of the desert at sundown.

Perhaps all these things are true, but I should be sorry to think so. If this is the real trend of human evolution, we who represent the "unfit" type, may well pray for a speedy extermination. I suspect that for many of us students of nature the appeal of natural scenery is of the same kind, though vastly more compelling, than that of either music or poetry.

I am quite aware that I am exposing myself to the charge of leaving the field of scientific discussion and of resorting to sentiment and rhetoric. This in a sense may be granted. But I doubt whether any harm can come from our appealing to both motives—the scientific and the sentimental—in a discussion of this many-sided question. Who would be willing to say, moreover, that these two motives are wholly distinct from one another? Is there so little in common between the naturalist and the nature-lover? Perhaps most of us would wish to be regarded as both. However that may be, the two have a common interest in promoting the enterprise before us, even though they may speak a widely different language.

The need for prompt and drastic action to save our native fauna, especially the birds and mammals, has been ably and forcibly set forth by various recent writers. It is scarcely necessary for me to rehearse the gloomy chronicle of extinct and vanishing species which has been recorded by Hornaday[2] and others. Let us not, however, focus our attention too exclusively upon these relatively few examples which are so conspicuous—the mammals and birds which are sought for as sources of food or feathers or fur.

Many states retain but few traces of their original assemblages of animals or plants in general; many possess little that can in any true sense be called natural scenery. Forests are vanishing, brush land being cleared, swamps drained and the desert irrigated. "Reclamation" is being pushed forward with an almost religious fervor.

Cattle and sheep are grazing everywhere upon our meadows and hillsides, with a resulting diminution of that wealth of resplendent coloration which was formerly the glory of California. Not only are our wild flowers disappearing through the agency of grazing animals, but the same is true of various birds, whose nests are built upon the ground.

No agency of civilization has perhaps been more potent in bringing large numbers of our people into close contact with

[2] "Our Vanishing Wild Life," New York, Chas. Scribner's Sons, 1913; "Wild Life Conservation in Theory and Practice," New Haven, Yale University Press, 1914. See also the able and forceful article by W. G. VanName, entitled "Zoological Aims and Opportunities," *Science,* July 25, 1919.

nature than has the automobile. But there is another side to the story. The automobile is fast opening up to the week-end excursionist the remotest mountain fastnesses and the wildest solitudes of the desert. Game is shot, much of it doubtless contrary to law, wild flowers and native shrubbery are gathered in reckless profusion, disfiguring rubbish is scattered broadcast, and fires are started which burn over thousands of acres of brush or forest land. Most of these fires, according to professional foresters, are due to carelessness. I think I am safe in adding that most of them have been made possible by the automobile.

The splendid redwood forests of the northern California coast belt—perhaps the finest forests on the American continent—are falling before the axe and the saw of the "lumber king" and the air for much of the year is hazy with the smoke of the burning brush and trees which have to be thus removed before the fallen giants can be cut up and dragged away for the market. The result is a scene of appalling desolation for years to come. When these forests are gone—as they will be, save for a few remnants—our fertile-brained inventors will discover quite acceptable substitutes for redwood lumber, and the building business will continue "as usual." But we shall never find any acceptable substitutes for the redwood forests, which it took nature thousands of years to produce. It is true that in the case of this particular tree a second growth may reforest an area which has been logged over or damaged by fire. But this is a slow process, and we can not be sure that the same plant associations will establish themselves as existed previously.

Even the desert, which has long furnished interesting problems to the naturalist, as well as inspiration to the poet and the painter, seems doomed to wholesale invasion and exploitation. To make the desert "blossom as the rose" has for ages been looked upon as typical of man's conquest over nature, and the wonderful achievements in our own Southwest stand in the front rank of such efforts. But we can not overlook the tragic side of the picture. The limitless vistas of picturesque desolation lose much of their mystery when we find that they are threaded in all directions by automobile roads, and when the eye is everywhere confronted by scattered rectangular clearings, due to the fruitless efforts of would-be desert farmers. The highly interesting and picturesque plant associations in the western portion of the Mojave Desert are being rapidly destroyed by so-called "settlers" who are probably not getting enough out of the land, in most cases, to pay expenses. The weird and beautiful tree-yucca, a plant so typical of our California desert landscape, is now being largely used for various commercial purposes. I know of at least one company, organized with the particular object of exploiting these yucca products. As this is a tree of extremely slow growth, we may expect its practical extinction within large areas in the near future.

Where, then, has our discussion thus far led us? Are we to check the growth of population, arrest the march of progress, and withdraw from a large part of the land which we have occupied? Such a proposal is, of course, ridiculous. What is worth serious consideration is an insistence upon the conservation of our fauna and flora and natural scenery to an extent hitherto not contemplated by our people or our government.

Large tracts of land, representing every type of physiography and of plant association, ought to be set aside as permanent preserves, and properly protected against fire, and against every type of depredation. Here would be included desert and chaparral, swamp land and seashore, mountain and prairie. All this would doubtless cost vast sums of money, but what is money for? The question is really one of relative values.

Instead of game-laws, we should have a nearly absolute prohibition, both within and without these reservations, of the shooting of every wild mammal or bird not definitely known to be harmful to man. Exceptions might be made in certain cases, but only after careful consideration by competent and disinterested persons.

All lumbering operations should be under the supervision of the government. Throughout large tracts, such operation should be absolutely prohibited, and where permitted, the trees should not be removed faster than their natural rate of replacement. Exception is of course to be made of land which is to be permanently cleared for agricultural purposes. But the question as to which areas should become farming lands, and which ones permanent forests ought to be decided by disinterested experts, with sole reference to the higher welfare of the public and of posterity, and not on the basis of purely local circumstances or the accidents of private ownership. Scientific considerations, such as the advantage of maintaining the continuity of a given forest area, should figure here, among other motives.

The fact that *all* of our redwood forests, with two unimportant exceptions, are now in private hands and are fast disappearing, shows how far we are from the realization of such an ideal. Fortunately, in this particular case, a public-spirited group of citizens have taken steps which seem likely to result in the reservation of a considerable tract of these unique forests.[3]

Another part of our program should be a vastly more adequate system of fire protection, and of game-law enforcement. This may be said without reflecting upon the competency of the various forest and game wardens who are entrusted with these duties at present. Many of them doubtless do the best possible with the utterly inadequate resources at their disposal. Who can read of the continuous series of holocausts which devastate the Rocky Mountain and Pacific Coast States every summer without realizing that the means of fire protection must be utterly inadequate? The president of the American Forestry Association is quoted as saying recently (N. Y. *Times*) that although "the United States Forest Service spent more than a million dollars fighting these fires in July alone, . . . the fire protection measures in neither national, state nor private forests are sufficient to properly protect them."

At the time of the recent fire in the California Redwood Park at the Big Basin, the state forester made the statement that $140,000 had been asked of the previous legislature for fire protection during the present biennium, whereas only $25,000 had been appropriated for this purpose. He attributed the frequency and the disastrous results of forest-fires during the past season to this lack of adequate funds. We can not help wondering how the thrifty taxpayer invested the few cents which were saved him by this economy on the part of his representatives at Sacramento.

As for game-laws, it is widely believed that these are habitually violated by dwellers in the more remote sections of the state. Adequate protection would doubtless mean a much greater expense, but here again we are met with the question: would it not be worth while?

The whole problem with which we have to deal is, after all, one of relative values. What are the things that are most worth doing—and paying for? Our whole plea for the conservation of these considerable fragments of nature rests, of course, upon the *value of these to mankind.* What the wishes of the animals and plants are in this matter does not much

[3] Save the Redwoods League. For information, address Mr. R. G. Sproul, Sec.-Treas., University of California, Berkeley.

concern us. But we must recognize the existence of various standards of value, and I believe that there are standards far higher than are generally recognized and applied to this question.

Our reasoning is too often like that of the farmer who was asked why he wanted to add to the size of his farm. "So as to raise more corn," was his ready reply. Pushed by his questioner to tell why he wanted to raise more corn he said; "So as to feed more hogs." And the sale of his hogs, he declared, would enable him to buy more land, in order to raise more corn, in order to feed more hogs, and so on to the end of his natural life.

I hope I may be pardoned for quoting from another article[4] in which I have asked the question:

> What will the increased population do which is made possible by a greater food supply? It may all mean a merely *quantitative* increase in the total amount of living—by no means a self-evident advantage, according to my way of thinking. The great mass of humanity is engaged in discharging the purely vegetative functions of the social organism, in keeping alive the individual and the race, and in maintaining a certain low minimum of comfort. To merely increase the total amount of this vegetative activity in the world seems to be widely accepted as one of the chief goals of human endeavor.

Once more:

> Which is the higher aim to make room in the world for the greatest possible number of human animals, or to make the world a more interesting and intelligible [and beautiful] place to live in: to feed the belly or to feed the brain?

Again, it must be insisted that as things now go, our world is destined to be populated up to its capacity, within a comparatively brief period of time. In that day, if not before, we shall be faced with the problem of correlating the rate of reproduction with the means of subsistence under endurable conditions of life. Would it not be equally possible, and vastly more desirable, that we should strike this equilibrium some time before the inhabitable land had all been occupied? I think there can be no difference of opinion as to which of these alternatives offers the greater prospect for future human happiness. This mad rush to fill up every nook and cranny of the world is prompted in a large degree by national ambition for power; partly also by the greed of the business promoter and the real-estate shark. These are the greatest foes of any movement toward leaving the world truly habitable for the future.

[4] Scientific Monthly, March, 1919.

I trust that I shall not be charged with voicing any general depreciation of what we call "man's conquest of nature." To a large extent this has been desirable; and in any case it has been the necessary price which we have had to pay for our advance beyond savagery. Many things in nature have had to be used, even though this use has destroyed their beauty and their interest as objects of scientific study. What we insist upon is a fuller recognition of the non-utiliarian motives, or, we should perhaps say, a broader conception of what constitutes *usefulness.*

Why is it that even we who claim the title of scientists are always so timid and shamefaced about declaring our real motives for the protection of living things. We must save the songbirds, because they eat up cut-worms and the seeds of noxious weeds. We must save the game-birds, in order that they may remain and be successfully hunted by future generations of sportsmen. We must save our forests as future supplies of lumber and as a protection to watersheds; we must save multitudinous other things because we may still discover uses for them now unknown.

Is all this because we feel that we are the only ones who are highminded enough to appreciate our own lofty motives, and that neither the public nor its elected representatives can be taken into our confidence? Such a pessimistic judgment may possibly prove to be warranted, but there are several reasons for working on the opposite assumption, if only as an experiment. In the first place, if the public and its representatives in legislature and congress are really as sordid as we credit them with being, our own attitude is calculated to confirm them in their sordidness. If even the savant assents to the proposition that practical utility is the only standard of value, what shall we say of the hoi-polloi? We are helping to create a background of public-opinion which is certain to block every serious move toward the reservation of large fragments of nature for non-utilitarian ends.

In the second place, all such more or less disingenuous justification of our endeavors in this direction can not fail to react upon ourselves. Can our intellectual honesty help being blunted by our habitually acquiescing in a theory of life which at the outset we must have stanchly repudiated?

The reader has doubtless long been patiently waiting to learn whether my whole effort was to expend itself in exhortation, or whether I had a definite program of action to offer. Personally, I have no very definite program; much less do I wish to pose as a leader in a movement of such vast magnitude. Least of all do I wish to slight the large volume of important and successful work in this direction which has been accomplished by many persons, including some of our foremost citizens. If my presentation of the case should result in renewed effort on the part of some of those who share these views; or if it should attract the attention of a few who had not given previous thought to the problem, my labors will not have been vain. I fear that there is only too much justification in the charge made by certain writers that we professional zoologists of the universities have not faced our plain responsibilities in this all-important matter. Can we refute the essential accuracy of Hornaday's rather ill-natured declaration that "fully 90 per cent. of the zoologists of America stick closely to their desk-work," not perhaps "soaring after the infinite and diving after the unfathomable," as he expresses it, but nevertheless "never spending a dollar or lifting an active finger on the firing line in defense of wild life."[5]

In similar vein, Van Name writes of the "easy-going indifference and irresponsibility of those who are the only ones who can fully realize the needs and urgency of the situation, and who should therefore feel it a duty to make others understand also."[6]

Now, while I have no very definite plan of campaign to offer to those who would like to devote some of their energies to this cause, I do feel at liberty to make a few suggestions. In the first place, this is an occasion above all others, where cooperative effort is necessary. The matter should be taken up seriously by the great national scientific societies. It may be mentioned here that the Ecological Society of America already has a "committee on the preservation of natural conditions for ecological study." This committee is in possession of considerable information which will doubtless be of value.

But the work of any of these societies would necessarily be for the most part of an advisory nature. Such a program could, of course, be carried out only under government auspices. Here, several different branches of the service are to be mentioned.

1. The National Park Service, already administers an area of about 10,000 square miles, comprising fifteen parks. The latter, of all parts of the public domain, probably come nearer to fulfilling the conditions required of a nature reservation in

[5] "Wild Life Conservation," p. 184.

[6] *Science*, July 25, 1919.

our sense of the words. They are inadequate for our purposes, however, in that they include only areas of exceptional scenic grandeur. The demand for extensive tracts, representing every type of physiography and of plant association, has not thus far been met. Likewise, the national parks are preserved primarily as "public playgrounds," and the public is admitted to every portion of these lands. Such playgrounds are doubtless among the important assets of the nation.[7] But there ought to be still other tracts, in which the fauna and flora are reserved primarily for the studies of the botanist and zoologist —ones in which the native life will be more adequately safeguarded than at present. It does not seem to me utopian to try to have the National Park Service or some other bureau of the government adopt, and publicly and explicitly avow, this additional motive for reserving tracts of land from settlement or depredation—namely, the permanent preservation of the native fauna and flora by reason of their value to science, and to the higher interests of generations to come.

2. The National Forest Service, which administers nearly a quarter of a million square miles, an area about as large as the New England and Atlantic States combined. One might be disposed to think that in setting aside these huge areas, the government had done far more than the most sanguine conservationist would have a right to ask. But we must note several important drawbacks, from the point of view of the scientist. To begin with, the national forests are located chiefly in the more elevated and mountainous regions of the country. Very little of the lowland forests—none, indeed, of the coast redwoods—are thus included. In the second place, lumbering, although on a restricted scale, is permitted in the National Forests, as are also grazing, hunting and camping. All of these last conditions are quite incompatible with the interests of botany and zoology, and they are likewise incompatible with the aims of those who would like to retain great tracts of virgin forest as a heritage for the future. Would it not be possible to reserve certain tracts—wisely chosen by distinterested experts—from which the lumberman, the hunter and the cattleman should be forever excluded?

3. The United States Biological Survey has established a considerable number of bird and game refuges, in which the

[7] Especially to be commended is the plan to have trained field naturalists detailed for duty in these parks during the summer season, for the purpose of giving instruction to such visitors as may be seriously interested in the natural history of the region.

shooting or molestation of birds is prohibited. There are 74 such refuges thus far established, these, in every instance, being selected with reference to their value as nesting grounds. Attention must be called, however, to the lack of any guarantee as to the permanency of such sanctuaries. Two of the most important of them, lying within Oregon and California, were set aside as bird refuges by President Roosevelt in 1908. One of these, Lower Klamath Lake, has been recently seized upon by the Reclamation Service, and is already practically ruined as a breeding ground for water-fowl. This is all the more reprehensible, since the director of the Reclamation Service has recently admitted, after investigation, that the potential value of these marsh lands for agricultural purposes is doubtful.[8] The second of these reservations referred to, that of Malheur Lake, seems about to undergo the same fate.

4. Aside from these branches of the federal government, we have certain departments of various state governments which administer more or less extensive state forests and game refuges.

The problem before those biologists who are interested in the aims above set forth is to develop an organization which will be able to mediate between themselves and the various state and national agencies through which such ends could be accomplished. An entirely new society might be organized for this purpose, but the general sentiment of scientific men at present seems to be against multiplying these societies. It has been suggested by one of my correspondents that a new section of the American Association might be created for this purpose. Another suggestion is that the National Research Council might properly serve as a clearing-house for such efforts. I am not in a position at this time to make a recommendation in the mattter. The main thing at present is to induce the various scientific societies, national and local, to take the matter up and discuss it seriously.[9] This might result in the formulation of a wise plan of action and it would at least, serve a good purpose if it succeeded in rousing from their present apathy many of those who could be of considerable service in the movement. Wise leadership is of course necessary, here as everywhere.

[8] Cited by W. L. Finley, state biologist of Oregon, in *Portland Oregonian*, October 26, 1919.

[9] I must again urge the fact that the Ecological Society of America has already made a beginning in this direction.

Two further comments seem to me worth making before I close this rather long harangue.

One is that we should state our objects and aims with absolute frankness. If we believe, as I hope we all do, that scientific, esthetic and higher humanitarian considerations are strong enough to stand upon their own feet, let us not justify every step that we take by appeals to economic and crassly utilitarian motives. If we favor, as perhaps many of us do, a practically total prohibition of the hunting of harmless species for sport, let us not league ourselves with the sportsmen themselves, and pretend that we are merely trying to save the "game" for future generations of hunters. It is certainly an unfortunate circumstance, to my mind, that most of the present enforcement of game-laws is paid for out of funds derived from the issuance of hunting and fishing licenses.

The second and last of my comments is a repetition of the warning that this question is an urgent one, and that emergency measures are necessary. With an increasing population, modern implements and vastly more efficient means of transportation, more destruction can be wrought in a single year than was formerly possible in a decade. Then too, we have recently had the inevitable raid upon our resources of all sorts necessitated by the late war, and the equally inevitable raid which is bound to result from the post-bellum problems of reconstruction. A bill is now before Congress, setting aside five hundred million dollars from the treasury for the purpose of "reclaiming" a large part of such usable land as has not yet been developed agriculturally. This measure has been introduced ostensibly in the interest of the returned soldiers.

I do not know how many of these deserving men have expressed any desire for farming lands. The sponsor for this bill may have data on the point. But in any case, a certain considerable fraction of our unreclaimed land ought to be reserved from settlement. Such a step would be in the interest both of science and of a truer humanitarianism which sees even greater benefits to our race than those which may be conferred by lumber mills and irrigation projects.

THE ORIGINS OF CIVILIZATION[1]

By Professor JAMES HENRY BREASTED

THE UNIVERSITY OF CHICAGO

LECTURE TWO

The Earliest Civilization and Its Transition to Europe, III

As the Greek nomads ceased to wander and gradually shifted to a settled town life, they found Phœnician merchandise in every harbor town. The very garment which the Greek townsman wore he called by a Phœnician name (*chiton*) as he heard it from the Oriental traders along the harbor shores. As he continued to receive these products of Oriental art and industry, the Greek slowly learned the craftsmanship that produced these things. Indeed there is every indication that there were plenty of Phœnician workshops on Greek soil. Meantime the Phœnicians or their kindred the Arameans had long since devised an alphabet, based on Egyptian writing, and were thus employing the first system of writing made up exclusively of alphabetic signs.[28] Continuous business intercourse with the Phœnician craftsman and merchant naturally impressed upon the Greek what a great convenience the Phœnician possessed in his written records of business. Thumbing the Phœnician's papyrus invoices, the Greek tradesman eventually learned the meaning of the curious alphabetic signs, and then began to use them himself for the writing of Greek words, employing some of the

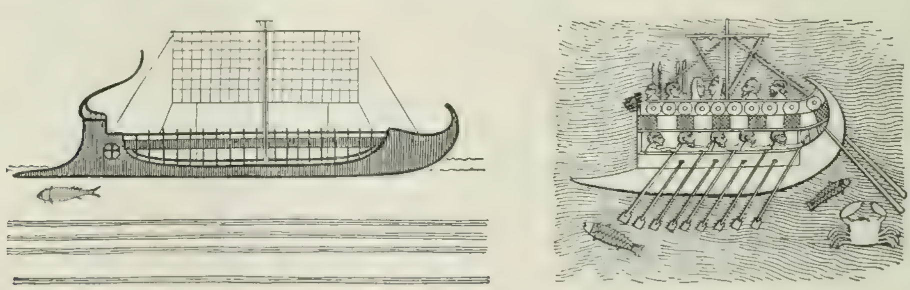
[1] Delivered before the National Academy of Sciences in Washington, D. C., April 28 and 29, 1910, as the seventh series of lectures on the William Ellery Hale Foundation.

[28] The origin of the so-called Phœnician alphabet and its transmission to Greece form a difficult problem, far more complicated than the above simple statement would indicate. The solution of the problem has been greatly furthered by the discovery of a new script in Sinai, which has been brilliantly employed by Alan. H. Gardiner, "The Egyptian Origin of the Semitic Alphabet," *Journ. of Egyptian Archæol.*, III., Part I. (Jan., 1916), with additional observations by A. E. Cowley, "The Origin of the Semitic Alphabet," *ibid.* See also H. Schaefer, "Die Vokallösigkeit des phoenicischen Alphabets," *Zeitschr. für aegyptische Sprache*, LII., 1915, 95–98; R. Eisler, "Entdeckung und Entzifferung kenitischer Inschriften aus dem Anfang des zweiten Jahrtausends vor Christo im Kupferminengebiet der Sinaihalbinsel," *Biblische Zeitschrift*, XV., 1918, 1–8; K. Sethe, *Nachrichten der kgl. Goett. Gesell. der Wissensch., Phil.-histor. Klasse*, 1917, 437ff.; and Breasted, "The Physical Processes of Writing in the Early Orient and their Relation to the Origin of the Alphabet," *American Journ. of Semitic Languages*, XXXII., 1916, 230–248.

FIG. 117. PAINTINGS ON AN ARCHAIC GREEK VASE SHOWING THE EARLIEST KNOWN SIGNATURE OF A GREEK VASE-PAINTER. The vase-painter's signature is at the extreme right end at the top of the lower row. It reads "Aristonothos made it," and dates about 700 B.C., at a time when the Greeks were just learning to use Phœnician writing.

signs as vowels, which were not represented in the Phœnician alphabet.

By 700 B.C. the Greek potters were writing their names, like trademarks, on the vases they produced (Fig. 117). But the Greeks soon found the Egyptian paper offered them by the Phœnician merchants of Byblos the most convenient writing material, and they called it *byblion* or *biblion* after the Phœnician port from which it came, as we call Chinese porcelain "china" or rich textiles originally from Damascus "damask." This word gave rise to the various words for library used by a large part of Europe, like the French "bibliothèque"; and our



A B

FIG. 118. AN EARLY GREEK SHIP (LEFT) AND THE PHŒNICIAN SHIP FROM WHICH IT WAS MODELED (RIGHT). After the 15th century B.C. the Phœnicians seem to have introduced a change in the earlier model of their ships (Fig. 116), altering the high bow into a beak which was below the surface of the water. Whether this change was of Phœnician origin or not is a little uncertain. The Phœnician model above (right) is from a relief of Sennacherib, showing that the Assyrians adopted Phœnician shipping, as did the Persians also. A large proportion of the Persian ships at Salamis were Phœnician. (From the author's "Ancient Times," by permission of Ginn & Co.)

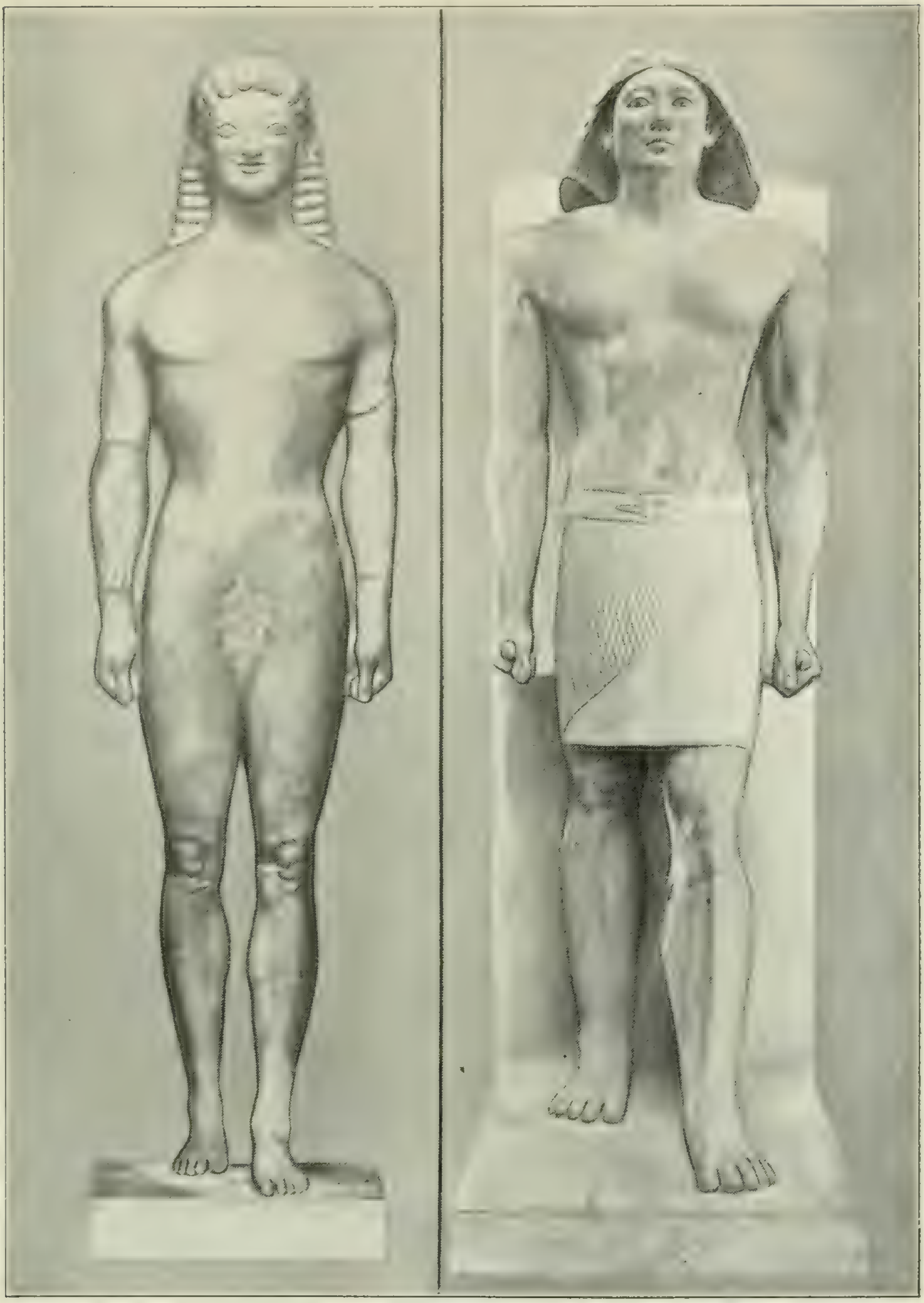


FIG. 119. ARCHAIC GREEK STATUE AND EARLY EGYPTIAN STATUE BY WHICH IT WAS INFLUENCED. The similarity, or we may say actual identity of posture, even including the left foot thrust forward, shows clearly that this archaic Greek sculpture grew up under Egyptian influence. (From the author's "Ancient Times," by permission of Ginn & Co.)

own word "Bible." Another word then commonly used for Egyptian paper was "papyrus," which with loss of the classical ending "us," and change of a single vowel has given us our word "paper." Thus after the destructive Greek invasion had crushed out the earliest literary culture that had arisen in Europe, both writing and its physical equipment were again

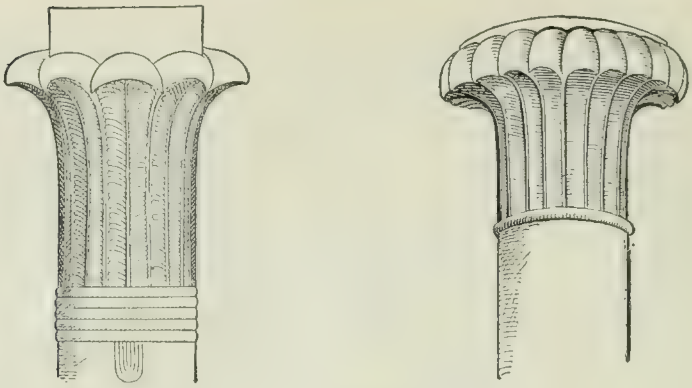


FIG. 120. EGYPTIAN PALM CAPITAL AND HELLENISTIC PALM CAPITAL COPIED FROM IT. (From the author's "Ancient Times," by permission of Ginn & Co.)

introduced into Europe from the Orient. Such contributions from Oriental life make it perfectly just to say that Europe was at that time receiving civilization from the Orient *for the second time.*

Meantime the Greeks had rapidly learned shipbuilding and navigation from their Phœnician competitors (Fig. 118). In doing so they adopted a new Phœnician model with beaked prow, quite different from the old Ægean model from Egypt (Fig. 84) with both ends turned up. This again illustrates how little of the old Ægean culture had been able to survive the Greek invasion. As the Greek maritime ventures extended to all ports of the eastern Mediterranean, Greek merchants and gradually also Greek travelers, came into direct and first-hand contact with the vast fabric of civilized life in the Near Orient, especially after 600 B.C. The travels of Solon, Hecatæus, Herodotus and Plato will occur to very reader. It should be remembered that in the times with which we are dealing the Greek citizen could walk entirely across a town like Athens or Ephesus in five or six minutes, and there was not a Greek city in existence which could not be traversed from edge to edge in ten minutes or less. When the Greeks first visited the Orient all Greek buildings, including the temples, were of sun-dried brick, and the supports or piers were of wood. As to statues, a wooden head surmounting a post draped with clothing was enough.

Under these circumstances it is not remarkable that archaic Greek sculpture shows unmistakable evidences of Egyptian influence (Fig. 119). The impression of the magnificent cities of Egypt and Asia upon the minds of travelers like Hecatæus and Herodotus was not exhausted in literary expression alone. Greek builders must likewise have seen these cities and added definite impressions as well as sketches to the vague references to the splendors of the Orient with which all Greeks were familiar in the Homeric poems. Greek architecture then responded sensitively and promptly to the tremendous stimulus of the vast architectural monuments of the Orient. Such tangible examples as the Egyptian palm capital, which we found in the pyramid temples in the twenty-eighth century B.C. (Fig. 83), copied by the architects of Pergamum in later times (Fig. 120), show that the diffusion of Egyptian architectural forms Europeward is a clearly demonstrable fact. Such evidence raises beyond doubt the Egyptian origin of the Greek Doric column (Figs. 121–122). Puchstein long ago made perfectly clear the Oriental origin of the Ionic column, and to such determination of the Oriental source of the individual column, Doric and Ionic, it is of great interest to add also that of the arrangement of assembled columns around an interior court. Such a complex architectural creation is by no means an obvious concept, which could arise independently on both sides of the Mediterranean. The ancestry of the Hellenistic colonnaded court becomes perfectly evident when we place such a court, as found in a Pompeian house, side by side with the Egyptian architect's temple court of the twenty-eighth century B.C. (Fig. 123). It can not be doubted, either, that the Hellenistic architects received the idea of their clerestory hall, which they called a "basilica," from the great colonnaded clerestory halls of the Egyptian Empire temples (Figs. 94 and 95), which thus became the ancestors of the basilica cathedrals of Europe (Fig. 124).

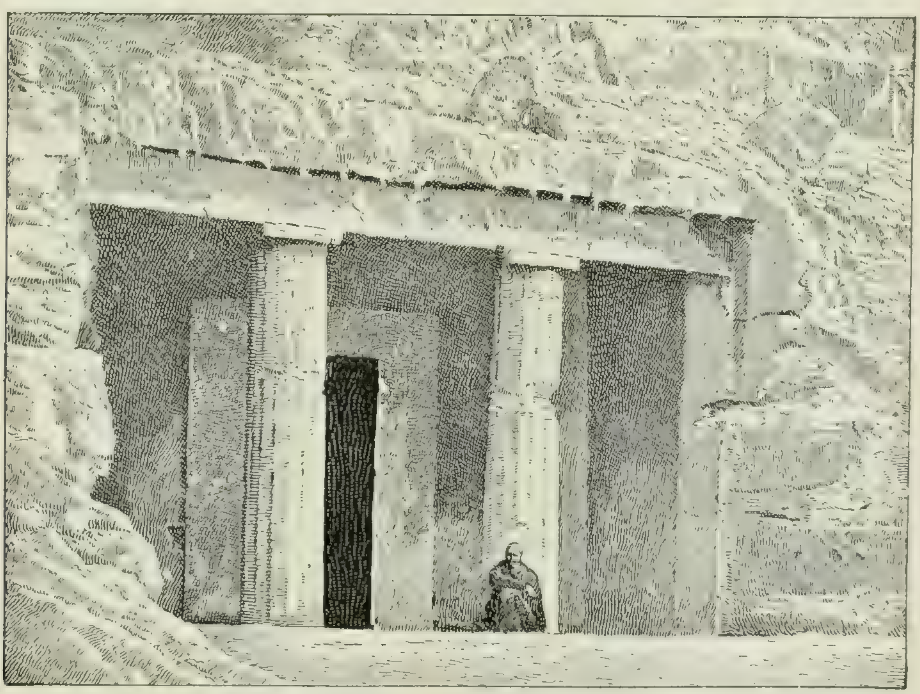


FIG. 121, FLUTED STONE PIERS OF AN EGYPTIAN TOMB A BENIHASAN. (19th century B.C.) These piers, which the Egyptians never adorned with a capital, were the ancestors of the Greek Doric column (Fig. 122).

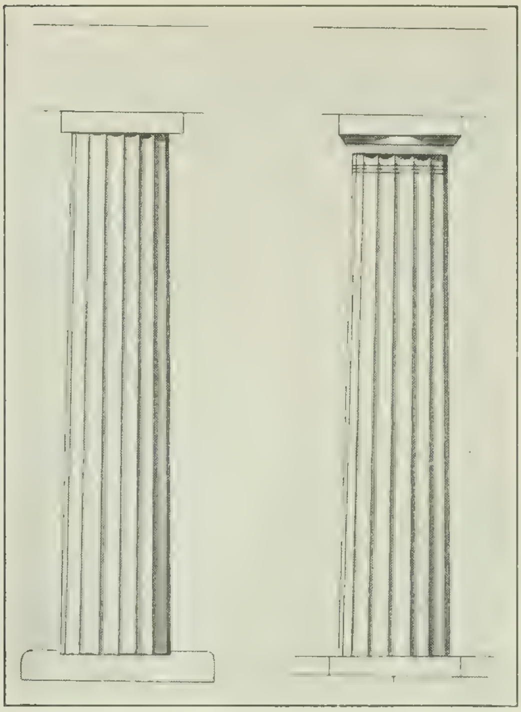


FIG. 122. THE OLD EGYPTIAN FLUTED STONE PIER AND THE GREEK DORIC COLUMN WHICH DESCENDED FROM IT. (From the author's "Ancient Times," by permission of Ginn & Co.)

Although it carries us chronologically far down the centuries, it is appropriate here to suggest a great architectural synthesis which I believe has not yet been made. The outstanding features of the Assyrian palace front, with its imposing central arch and lower arches on each side, were continued in the Parthian palace façade (Fig. 125, No. 2). It can not be doubted that Roman architects, seeing such structures in the Near East, drew the Roman triumphal arch from this source (Fig. 125, No. 3). Now when we recollect that in its nave and side aisles the clerestory hall presents a tripartite arrangement of floor, colonnades and roof, we see at once that the three arches of the old Assyrian palace front will answer to the front of the clerestory hall, part for part; the tall arch in the center corresponding to the high nave of the hall, while the smaller arches on each side correspond to the lower roof over the side aisles. In putting up a Roman triumphal arch as the front of the basilica cathedral, the architects of Europe were combining ancient Asia and Egypt.

It is further of great interest to observe that the tower with which the Christian cathedral was eventually embellished was likewise derived from the East (Fig. 126). The Hellenistic architects had found the model of their great lighthouse tower at Alexandria, the Pharos, in the old Sumerian temple towers of Babylonia. From such towers both Islam and Christianity finally drew the spires with which they adorned their sacred buildings. Thus Christianity, itself of Oriental origin, was housed in great sanctuaries, the fundamental elements of which had likewise come out of the East.

In a sane historical and cultural consideration of the career of man such indebtedness of Greek civilization to the Orient does not in the least detract from the unchallenged supremacy which the splendor of Greek genius triumphantly attained as the sixth century B.C. advanced. To recognize this indebtedness is but to acknowledge the operation of the same cultural processes in the Ægean, which must inevitably have been operative, because there were no reasons why the Greeks should be any more impervious to external influences than any other group of peoples. The Greeks were to be the first ancient people to gain complete freedom of the mind from traditional conceptions, and were thus to make intellectual conquests far surpassing the achievements of the Orient in the world of mind; but even in this realm they were not without their debt to the

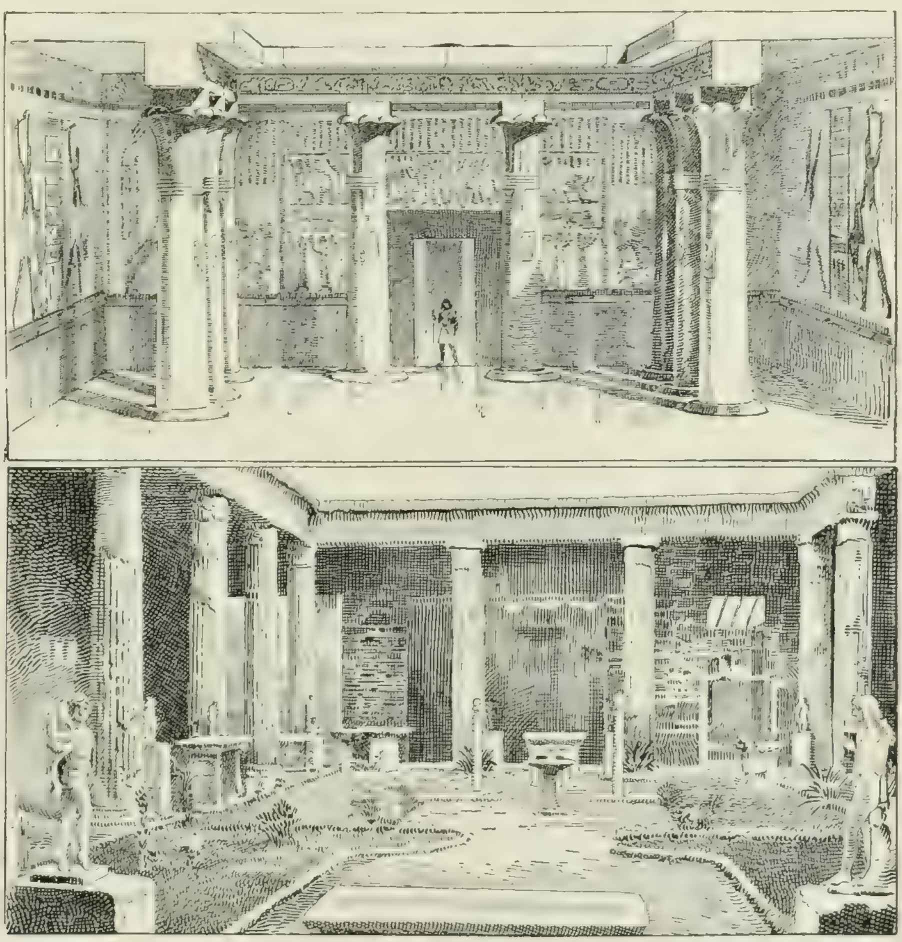


FIG. 123. THE ORIENTAL ANCESTRY OF THE EUROPEAN COLONNADED COURT. Above is the court of the temple of Sahure (Fig. 83), and below the court of the house of the Vetii at Pompeii, a building drawn from Hellenistic models in southern Italy. (From the author's "Survey of the Ancient World," by permission of Ginn & Co.)

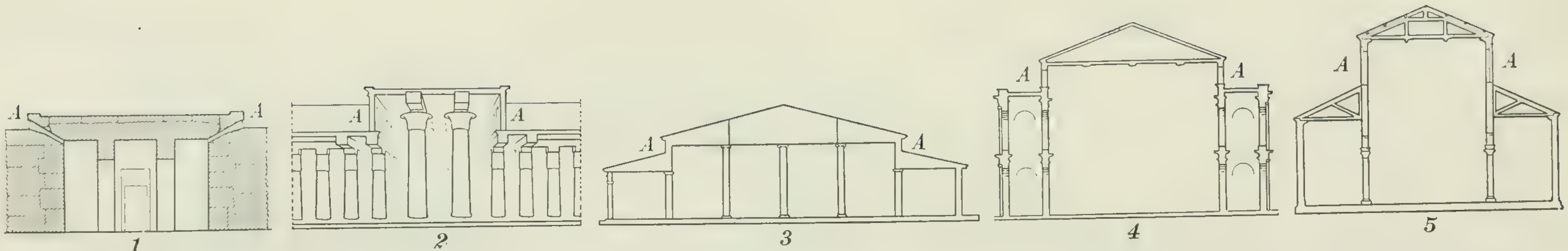


FIG. 124. DIAGRAM SHOWING THE ORIGIN OF THE CLERESTORY AND THE BASILICA HALL. The oriental ancestry of the basilica church is here evident. No. 1 is the earliest clerestory hall at Gizeh (29th century B.C., Fig. 79); no. 2 is the great Karnack clerestory hall 13th century B.C., Fig. 95); no. 3 is a Greek basilica hall of the third century B.C., showing the sloping roof necessary in a rainy country (Egypt being rainless); no. 4 is the Basilica of Julius Cæsar at Rome (first century B.C.); and no. 5 is a Christian basilica cathedral of the fourth century of the Christian Era. (From the author's "Ancient Times," by permission of Ginn & Co.)

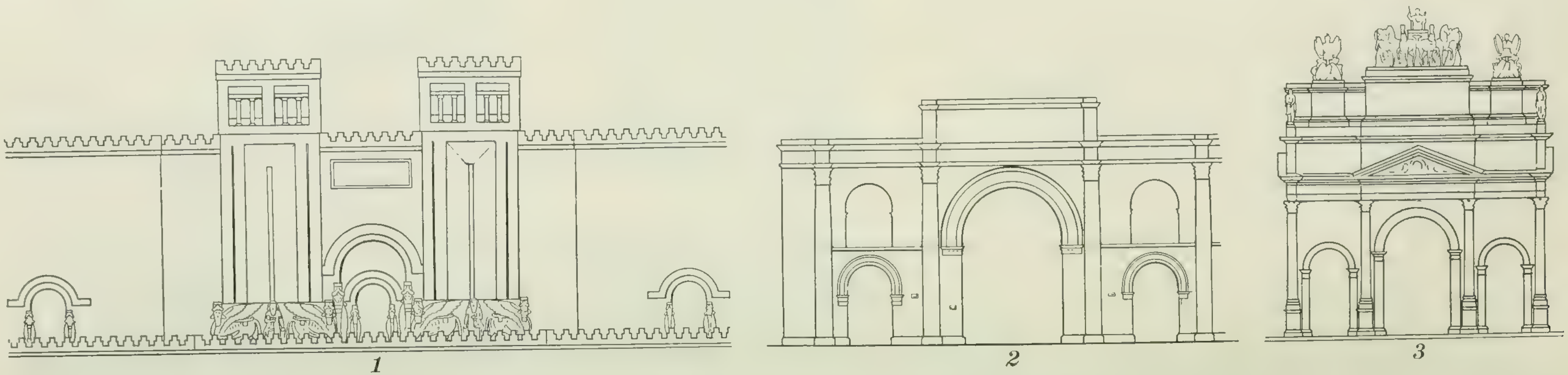
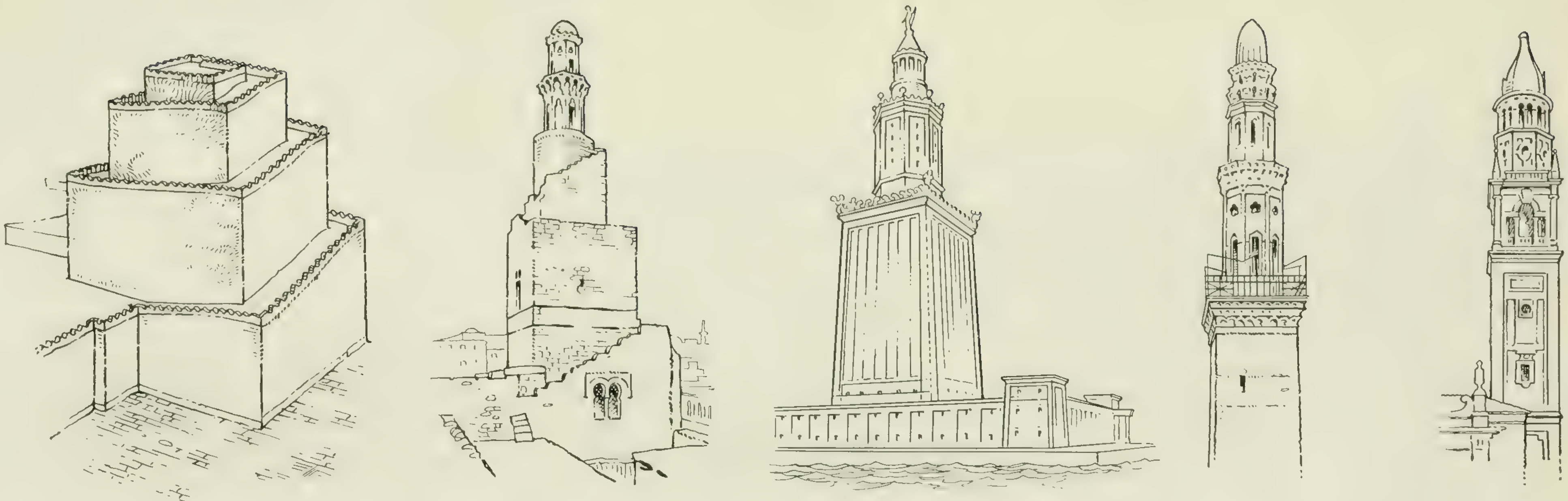


FIG. 125. THE ORIENTAL ANCESTRY OF THE ROMAN TRIUMPHAL ARCH. No. 1 is the Assyrian palace front (Fig. 111); no. 2 is a Parthian palace façade; and no. 3 is a Roman triumphal arch. (From the author's "Ancient Times," by permission of Ginn & Co.)



1 2 3 4 5

FIG. 126. THE ORIENTAL ANCESTRY OF THE TOWER IN WESTERN ARCHITECTURE, ESPECIALLY THE CHRISTIAN CHURCH SPIRE. No. 1 is the old Sumerian temple tower of Babylonia (Fig. 105); no. 2 is the minaret of the Mosque of Ibn Tulun in Cairo (ninth century A.D.), which still displays the winding ascent or ramp around the rectangular tower; no. 3 is a restoration of the Hellenistic lighthouse tower at Alexandria (third century B.C.; after Thiersch). Both nos. 2 and 3 display at the top a hexagonal member which forms the transition to a circular section crowning the whole. This is also found in early minarets of Western Asia, with a spiral ascent, as at Samarra. No. 4 is a minaret from an Egyptian mosque, while no. 5 is the spire of the church of St. John at Parmay, Italy. Both display the hexagonal and circular members at the top. (From the author's "Ancient Times," by permission of Ginn & Co.)

FIG. 127. A BABYLONIAN KUDURRU, COMMONLY CALLED A BOUNDARY STONE, BEARING EMBLEMS OF THE GODS: among them are signs later appearing in the zodiac like the scorpion and the archer.

accumulated knowledge of the natural world which they received from the Orient.

While we have thus followed the great drift of civilized influence as we can discern it especially in monumental forms which have come out of the Orient into the West, we have found that these things suggest influences less material and not so easily exhibited in visualized forms; just as the cathedral architecture of Europe, drawing its fundamental forms from the Orient, suggests the Oriental origin of the religion which it housed.

Among intellectual influences which the Greek traveler felt as he visited the Orient nothing attracted him more than the knowledge of the future which the Babylonian priest gained by observation of the celestial bodies. As we shall see, the Babylonian observer of the heavens did gain knowledge of the future, but not knowledge of the future of human affairs as he supposed and as he assured his Greek visitors. Astral religion among the Babylonians, already in the third millennium B.C. had led them to believe that they could read the future in the anticipatory movements of the heavenly bodies. They early noted the difference in the character of the planets and the fixed stars, and they began to group the latter into constellations associated with signs such as we see on the so-called boundary stones where the scorpion and the centaur already appear among the symbols of divinities invoked to protect the title of a land-owner (Fig. 127). But there was at first no comprehensive system of the skies, including all twelve of the signs of the zodiac.

Far down into the last millennium before Christ the observations made by the priests were solely for astrological purposes. They were crudely done and furnished but very vague data. Eclipses observed long after 1000 B.C. are not even accompanied by a note of the year, while the hour, if added, will be noted as one of the three watches of the night—watches which were not of fixed length. The claim that the Babylonians of the third millennium B.C. already knew of the precession of the equinoxes has been completely disproven.[29]

Only in the last seven centuries before Christ did the Babylonians pursue the study of the heavens for chronological purposes. A large body of astronomical tablets of this period show no indication of an astrological purpose. For the first time they contain observations including the data for both time and space, and with the inclusion of these elements astronomical science began.

The tablets of this age are of two classes, *observational* and *computational*. While the *observational* tablets deal incessantly with sun and moon and the relative positions of the two, they record especially the positions of the planets. This is done by noting each planet's position with reference to the fixed stars, but at first entirely without angular measurements, and if the planet was not far to the east or west of the fixed star, the position of the planet would be indicated by the phrase, "at the place" [of star so-and-so]. Later (especially the last four cen-

[29] See the work of the able Dutch astronomer-orientalist, F. X. Kugler, "Sternkunde und Sterndienst in Babel"; on this careful survey of Babylonian astronomical documents the above sketch is chiefly based.

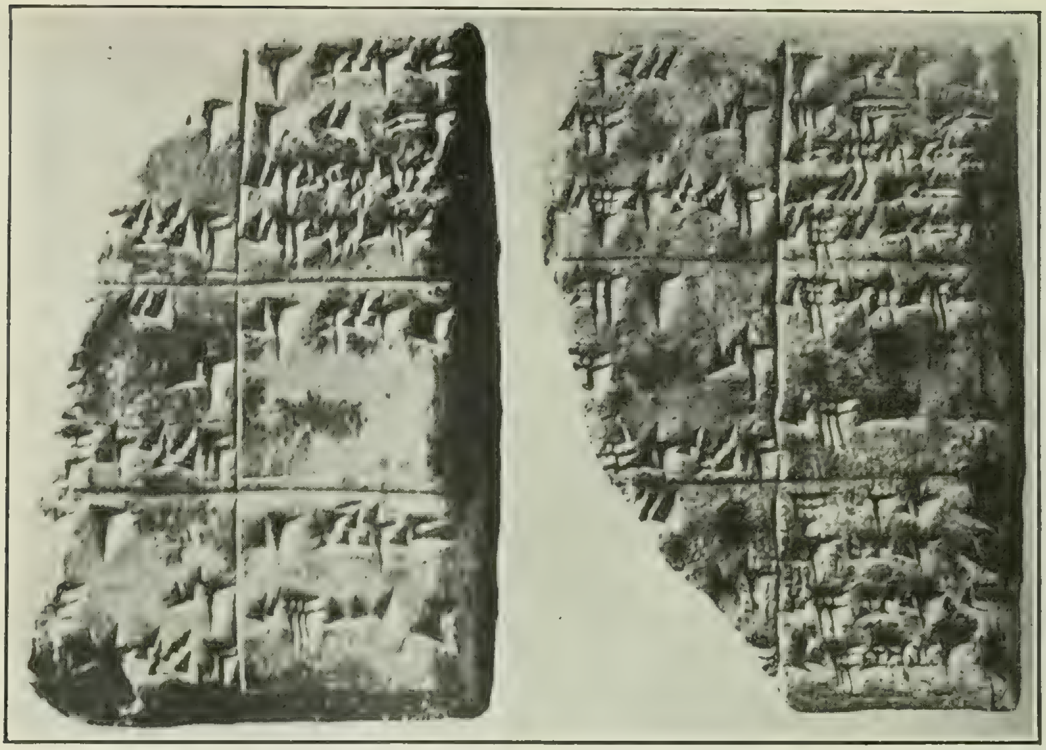


FIG. 128. CLAY TABLET PAGES FROM A BABYLONIAN ASTRONOMICAL ALMANAC FOR THE YEAR 425 B.C. (=Astr.–424) NOW IN THE MUSEUM OF THE UNIVERSITY OF PENNSYLVANIA.

turies B.C.) angular measurements were made in "cubit-degrees and inches" (Kugler). These observations resulted in the discovery of the eighteen-year lunar period, which the Greeks called "Saros," and with the aid of these the priestly astronomers constructed the first tables of the conjunction of sun and moon (syzygy tables).

Such observations also enabled the priestly astronomers to determine with astounding accuracy the synodic revolutions of the planets. In a region of wonderfully clear skies during eight months in the year, they were able to study even Mercury, which we rarely see, with such precision that by calculations based on his heliacal rising and setting they computed his synodic revolution as 115 days, 21 hours, 3 minutes and 50.9 seconds, a result which exceeds the computation of Le Verrier by only 16.3 seconds, while that of Hipparchus is in error by nearly a minute. In the computation of the mean synodic revolution of Jupiter, the Babylonian astronomers agreed with the results of Hipparchus within a fraction of a second.

In Fig. 128 we have before us a *computational* tablet of great interest, being the oldest such tablet as yet discovered. It is of a class called by the Greeks *ephemerides,* meaning the daily predictions of an astronomical calendar. This particular *ephémeris* is therefore a page from a Babylonian astronomer's almanac computed for the wear 425 B.C., the fortieth year of Artaxerxes I.

Each side of the tablet, obverse and reverse, is divided into two columns. In the *left-hand* column the astronomer has entered the monthly and lunar data: in the first line the length of the month, in the second the date of the full moon, and in the third the date of the moon's last visibility. There were thus three entries for each month. In the *right-hand* column a number of lines for each month predict the dates of the heliacal rising and setting of the planets and fixed stars. On the reverse, however, the column containing these predictions displays two additional predictions of the greatest interest. There are four entries for the month and they read as follows:

> On the first Mercury rises.
> On the third the Equinox.
> Night of the 15th, 40 minutes after sunset an eclipse of the moon begins.
> On the 28th occurs an eclipse of the sun. (Kugler.)

Kugler has calculated the dates of these two eclipses as having occurred on October 9 and 23, in —424 (astronomical), that is 425 B.C. The eclipse of the moon on the ninth of October was visible in Babylon; but that of the sun was visible only below the horizon of the city, and these ancient Babylonian astronomers who predicted it, were unable to see it. They evidently did not know beforehand that they would not be able to see it, and it should be noted that they were not in position to calculate the extent or place of visibility of a solar eclipse. It is thus doubtful whether they understood the nature of an eclipse. They were, however, able to compute the positions of the celestial bodies years in advance, especially those of the planets, giving dates and longitudes.

Of the instruments used in these observations, on which these remarkable calculations were based, we know nothing; but, however crude they were, it is quite evident that the Babylonians were the founders of astronomy and meteorology, and their amazingly industrious and discerning labors are not only of the highest interest in the history of civilization, but they are even of value to modern astronomy in the study of the moon.

It was into a world of researches and of astronomical knowledge such as we have suggested, that Greek travelers like Herodotus penetrated when they visited the east end of the Mediterranean, and especially if they went as far as Babylon itself. That the Greeks learned their astronomy in the beginning from the Babylonians there is no longer the slightest doubt. Even the name of the Babylonian observer and astronomer, from

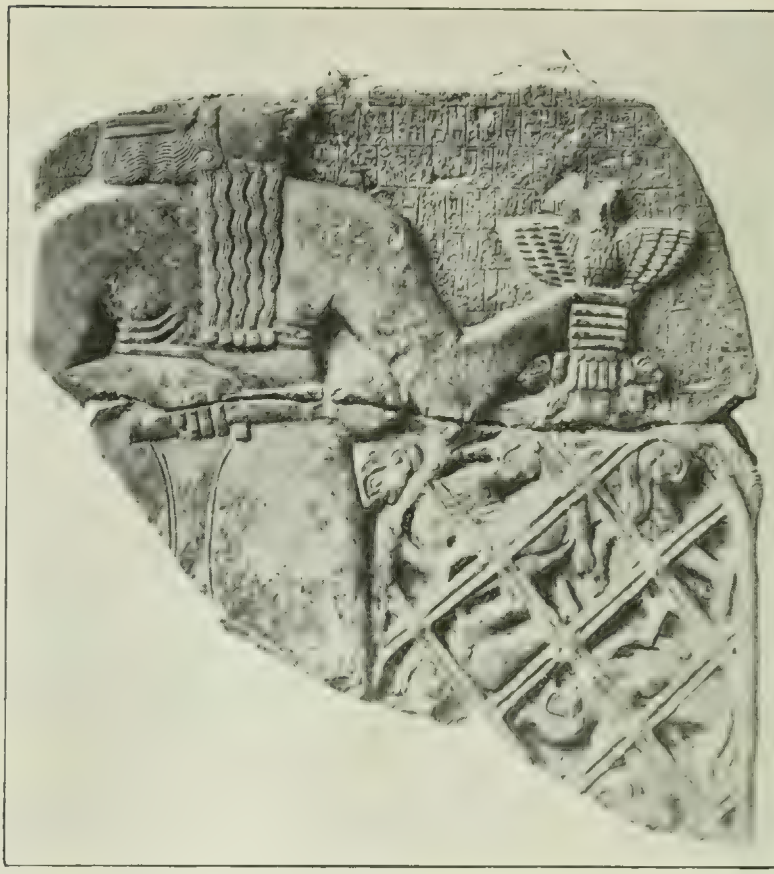


FIG. 129. NINGIRSU, GOD OF THE OLD SUMERIAN CITY KINGDOM OF LAGASH IN LOWER BABYLONIA, CARRYING AWAY THE ENEMIES OF HIS CITY IN A NET WHICH IS SURMOUNTED BY THE LION-EAGLE EMBLEM OF THE CITY. The emblem is the same as that found also in Figs. 102 and 103.

whose work the Greeks drew, has in one case been identified. A cuneiform tablet of moon data signed by the Babylonian astronomer Kidinnu is the work of him whom Strabo quotes as *Kidénas* and Pliny as *Cidenas*.[30]

Next to science and religion and intimately involved in the latter, the most powerful influence from the Orient has been the ancient tradition of the state and the place of the ruler and the god in it. It is of especial interest to note this fact now at one of the greatest moments in the history of man, when the last surviving traces of the Oriental conception of the ruler and the state have suffered destruction.[31]

[30] Bezold, "Astronomie, Himmelsschau und Astrallehre bei den Babyloniern," *Sitzungsber. d. Heidelberger Akad. d. Wissensch., Phil.-hist. klasse*, 1911, 2. Abhandlung, p. 16, quoting from Schiaparelli; Cumont, "Florilegium de Vogüé," pp. 159ff; and *Neue Jahrb. f. d. klass. Alt.*, 1911, XXVII., p. 8; and Kugler, BB. 122. A large mass of quotations from the cuneiform originals has been identified by Bezold and Boll in the astrological treatises of the Greeks (*Sitzungsber. der Heidelberger Akad. d. Wiss., Phil.-histor. Klasse*, 1911, 7. Abhandl.: *Reflexe astrologischer Keilinschriften bei griechischen Schriftstellern*).

[31] The following paragraphs to the end are adapted from the author's

On one of the early Sumerian monuments of Babylonia (Fig. 129), we see the god of the Sumerian city-kingdom of Lagash bearing in his mighty grasp the heraldic symbol of the state, surmounted by the eagle which was yet to cross lands and seas to become the American eagle: yonder the symbol of an Oriental autocracy, here that of a liberty-loving Western democracy. This scene, in the transparent symbolism of the Orient, epitomizes the early Oriental polity, picturing to us the victorious state upheld in the guiding and protecting hand of the god who was its head. Now this is of course a purely ideal scene—one that never existed except in sculpture.

It was possible, however, to express the same relationship between the god and the state in an actual scene, by employing a symbol of the god instead of a symbol of the state, and by putting this symbol of the god into the hands of a human representative of the state. By so doing the Oriental believed without qualification that he was thus introducing the potent presence of the god into earthly scenes and making him effective in earthly crises. In sculptured representations of the battle array, we find the Egyptians mounting a symbol of their god Amon in a chariot and driving with it into the midst of the fray (Fig.

FIG. 130. SYMBOL OF THE GREAT GOD OF THE EGYPTIAN EMPIRE AMON MOUNTED IN A CHARIOT READY TO BE CARRIED INTO BATTLE LIKE A MODERN FLAG.

discussion: "The Eastern Mediterranean and Early Civilization in Europe," Annual Report, Am. Hist. Assn., 1914, pp. 103ff.

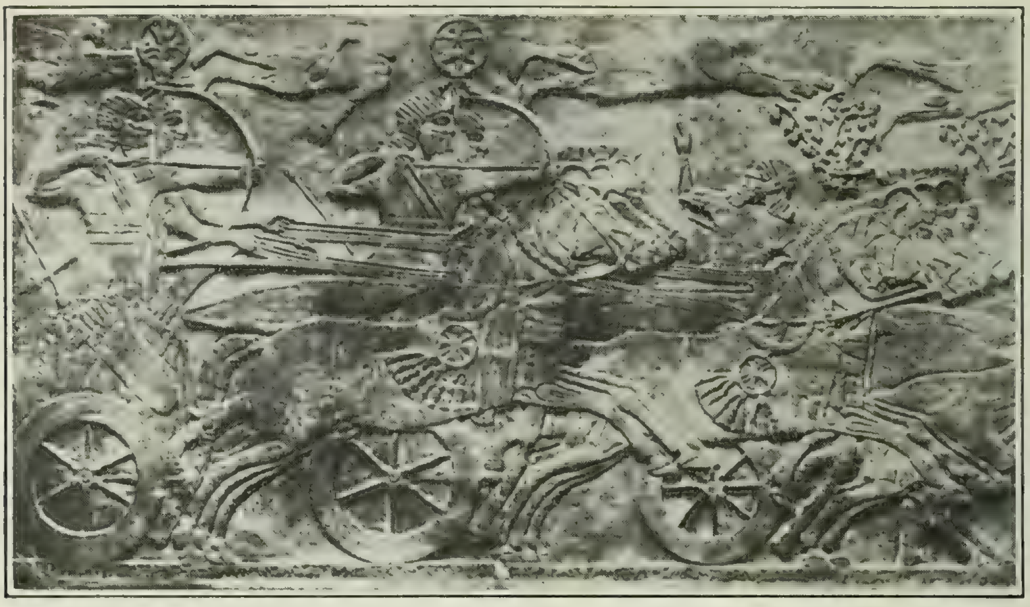


FIG. 131. SYMBOL OF THE GREAT GOD OF THE ASSYRIAN EMPIRE ASSUR MOUNTED IN A CHARIOT AND CARRIED INTO BATTLE LIKE A MODERN FLAG.

130), believing that the god was thus actually present and assisting in the conflict. We recall the similar use of the sacred ark of the Hebrews, which they sent into battle against the Philistines. The Assyrian sculptures exhibit the same custom (Fig. 131). When in camp the Assyrians housed their battle symbols of the god in a tent shrine, where the chariot bearing them stands in one corner, and priests minister to them as to the god of the state whose visible presence makes victory certain (Fig. 132). Such a custom was purely Oriental. The eagle standard of Jupiter Optimus borne at the head of the Roman legion can hardly have had any other origin.

Similarly we remember how Constantine later, thinking to honor the newly triumphant Christian faith, made a battle standard bearing a symbol of the Christ at the top, and this standard led the troops into battle. He too had a portable tent shrine for this standard, with daily ministrants attending upon it. Was it merely an accident that that Emperor who in the present war thought to possess Constantine's city and conquer the East in whose lore he was steeped—was it merely an accident that this Emperor continually reminded his troops that the power of divinity went with them in every battle?

This visible leadership of the god in the crisis of battle in the ancient Orient, was but one function in his guidance of the Oriental state. For the god was the source of the king's legal authority as the head of the state, and I know of no monument of the early East which so forcibly pictures this concept of the state as the sculpture surmounting the shaft which bears the laws of Hammurapi (Fig. 133). In this noble relief scene the Babylonian king at the left is depicted receiving from the god enthroned at the right the great code of laws which is engraved in thirty-six hundred lines around the shaft supporting this relief. The king thus receiving the law from the god enters into an intimate coalition, which makes the sovereign the infallible representative of the god, a representative whom no mortal would venture to challenge.

We have here a state which is a divine institution administered by a ruler who is the recognized agent of divinity. Of the Holy Roman Empire, in his volume on that subject, Lord Bryce remarks: "in order to make clear out of what elements the imperial system was formed we might be required . . . to travel back to that Jewish theocratic polity, whose influence on the minds of the medieval priesthood was necessarily so profound" (3d ed., p. 3). Had this distinguished historian's studies carried him back into the remoter reaches of the ancient Orient he would of course have recognized at once that what he calls "Jewish theocratic polity" was in fact only a very late manifestation of a conception of the state already wide-spread in the early East thousands of years before the Hebrew theocratic monarchy arose.

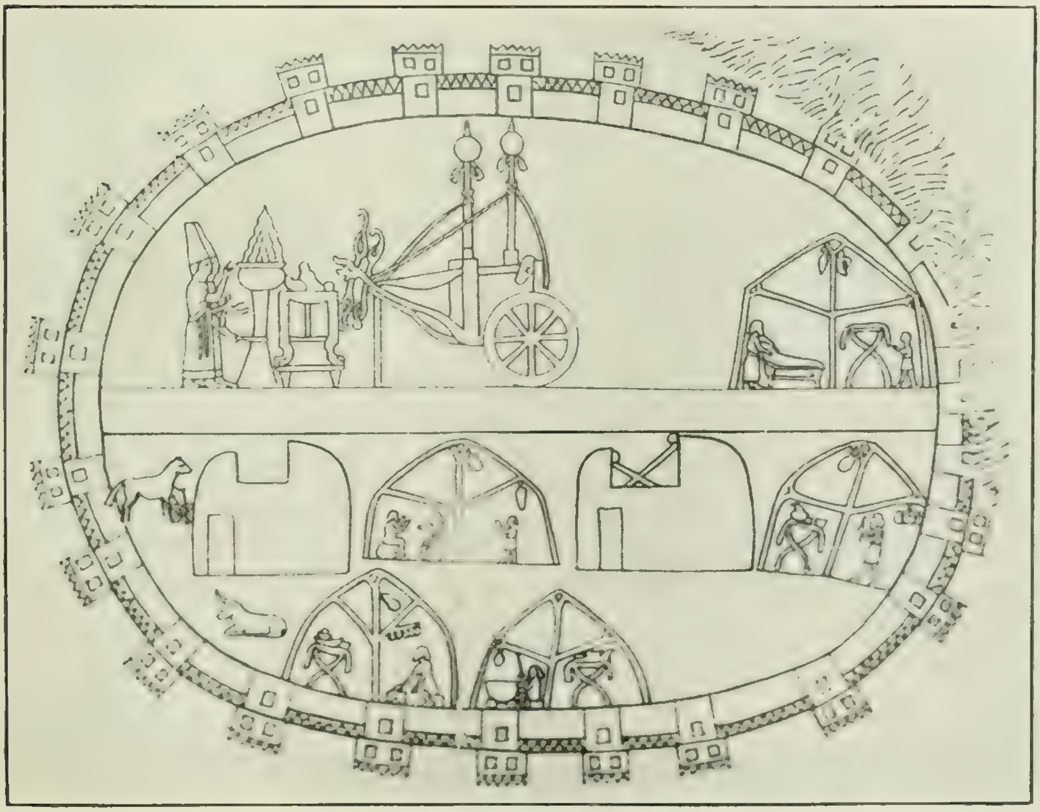


Fig. 132. Field Shrine of the Portable Battle Emblem of Assur, with Priests Ministering before it as to the God Himself.

FIG. 133. HAMMURAPI THE GREAT KING OF BABYLONIA RECEIVING THE LAW FROM THE SUN-GOD. (21st century B.C.) The king is at the left shrouded in a long garment. The god at the right is enthroned on a mount as suggested by the stones under his throne. The flame emblems rising from his shoulders show his character as a solar deity. The relief surmounts the shaft which bears his great code (Fig. 108).

Men who believed in such a state accepted absolute monarchy as a matter of course, and never raised the question or entered upon a discussion of the proper form of state. We can not here follow the course of this conception of the state as along with many other elements of the great fabric of Oriental civilization it entered Europe in the train of Alexander's conquests and, passing through the Oriental despotism of the Byzantine emperors, infected all Europe with the doctrine of the divine right of kings. In the person of the ablest and the most guilty of the fallen European sovereigns, a ruler who persistently proclaimed his belief in his own divine right—in the person of this ruler we of this generation have been watching the final and complete destruction of an ancient Oriental concept of the state and the sovereign.

But this hoary Oriental concept of the state, although much modified by democratic tendencies, did not stop on the other side of the Atlantic. Its influence was still felt in the New England town-meeting, which was as much a meeting of the church as it was of the town; and our pilgrim forefathers little dreamed that in the distant vista behind the venerable figure of Moses dominating their assemblies, there loomed the remote and colossal shadows of Cheops and of Hammurapi.

The reader will have discerned that the culture forces issuing from the birth-lands of civilization, which we have termed the Egypto-Babylonian group, have continued their profound influence on Western life, even down into our own day—a fact which is especially evident in the great historical religions, Judaism and Christianity. The particular purpose of these lectures, however, has been to reach much further back than is done by the historian, and in so far as such a slender sketch would permit, to marshal some of the more graphic and outstanding evidences which permit us to trace the rising life of man from the cave hunters of France and Spain in the Paleolithic Age, some ten or twelve thousand years ago, to the emergence of great civilized societies in the Near Orient, and the transmission of civilization from such communities to the shores of Europe beginning five thousand years ago. Even before the civilization of the Near East had been made possible by the development of writing and metallurgy, Europe had received cattle and grain from the Orient, as indispensable preliminaries to civilization (Fig. 134, first bracket). After the *first* transition of civilization from the Nile valley to southeastern Europe (Fig. 134, second bracket), the destructive invasion of the early Greek barbarians crushed the earliest civilization of Europe so that not even writing survived. The development of the Greeks was therefore accompanied by a *second* transition of civilization from the Orient to Europe, this time

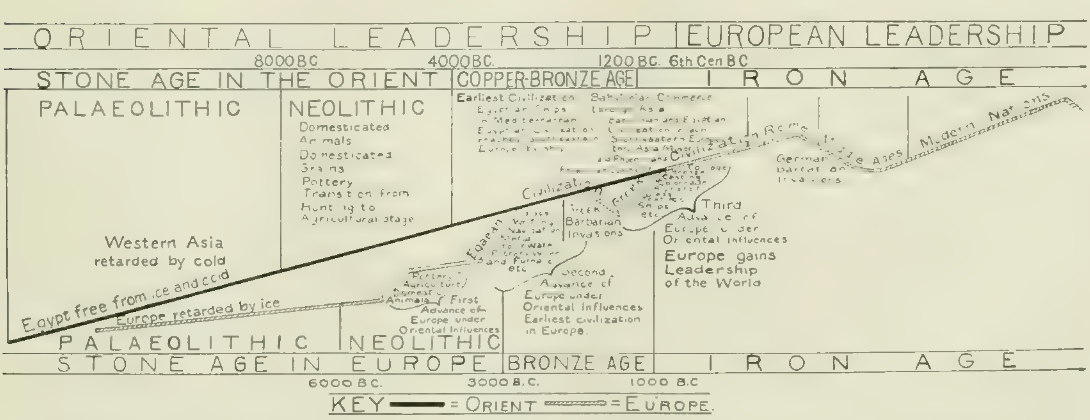


FIG. 134. DIAGRAM VISUALIZING THE RISE OF CIVILIZATION IN THE ORIENT AND ITS TRANSITON THENCE TO EUROPE.

from the entire Egypto-Babylonian group (Fig. 134, third bracket). But Hellenic genius never permitted the Greeks to remain merely passive recipients of culture from without. Building on foundations largely Oriental, they erected a splendid structure of civilization which nobly expressed their marvelous gifts, and brought them an unchallenged supremacy which was already evident in the sixth century B.C. The leadership in civilization then passed finally and definitely from the Orient to Greece. In recognizing this fact we have reached the culmination of that vast synthesis which we are the first generation of men to be able to make—a synthesis which enables us to trace the developing life of man from a creature but little superior to the simians, through unnumbered ages of struggle and advance, leading us from the cave savages of southern France through the conquest of civilization in the Orient, its transition to Europe, and thus through the supreme achievements of Greek genius, to the highly developed life of man at the present day.

THE MECHANISM OF EVOLUTION

IN THE LIGHT OF HEREDITY AND DEVELOPMENT

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V. The Cellular Basis of Ontogeny and Phylogeny

A. GERM CELLS AND SOMATIC CELLS

1. *Germ Cells the only Living Bond between Generations and Species*

IMAGINE the amazement and incredulity of the naturalists of a former generation, who thought of evolution only as the transformation of developed organisms under the influence of changing environment, if they could learn that to-day the greatest problems of ontogeny and phylogeny center in the structures and functions of the germ cells! And yet this is strictly and literally true. The germ cells form the only living bond not only between generations but also between species. The germ cells contain the physical basis not only of heredity but also of evolution. We know little about the changes taking place in germ cells which cause evolution, we are at present unable to initiate and control such changes, but at least we know where to look for them. The mechanism of evolution is at present largely unknown, but at least we know where that mechanism is located.

2. *Germ Cells and Somatic Cells are Fundamentally Alike*

When once the fact of the importance of the germ cells in ontogeny and phylogeny was appreciated there arose a belief that these cells must be essentially different from all other kinds of cells. Germ cells were contrasted with somatic cells and it was supposed that there must be a world-wide difference between cells which could give rise to new individuals or new species and those which constituted the various tissues of the body. And yet in many respects these cells are very similar. Both have a nucleus and a cell-body; in both the nucleus contains chromosomes that are usually of the same number, shape and relative size in all cells of a given species and while the cell-body of somatic cells undergoes marked differentiations in the various tissues these differentiations are probably no greater than the corresponding differentiations in the germ cells. Indeed the differentiations of a mature spermatozoon are probably as great as those of any muscle cell or nerve cell and the differentiations of the egg are as marked as those of any gland cell, while the differences between the male and female germ cells are quite as great as the differences between a muscle cell and a nerve cell. Furthermore there are many evidences that up to a certain stage of development cells may differentiate in one direction or another depending upon environmental conditions. Many cells which under certain conditions would have formed tissue cells may under other conditions form germ cells and *vice versa*, and this is especially true among lower organisms where cell differentiations appear more slowly and do not go so far as among higher forms. Such changes in the fate of a cell can not take place after differentiations have passed a certain stage; fully developed muscle cells or nerve cells can not become germ cells, nor can fully developed germ cells become tissue cells except by the process of embryonic development; but this means only that there is a critical stage in development beyond which differentiation is not a reversible process. All kinds of tissue cells as well as germ cells develop out of germ cells and it is evident that there is no *fundamental* distinction between the two.

3. *Nucleus (Germplasm) and Cytoplasm (Somatoplasm) are Fundamentally Different*

But while there is no fundamental difference between germ cells and somatic cells there is in every cell, excepting perhaps the very simplest organisms such as bacteria, a fundamental difference between nucleus and cytoplasm. Chemically and physically, morphologically and physiologically these two constituents of all cells are sharply distinguished. First of all there is a marked chemical difference between the two; the nucleus is acid in reaction, the cytoplasm alkaline; the nucleus contains a relatively large amount of phosphorus, the cytoplasm almost none at all; many compounds, especially nucleinic acid and nucleo-proteins are found exclusively in the nucleus. The nucleus is usually more dense and more highly refractive than the plasma.

But it is in morphological and physiological characteristics that the differences between nucleus and plasma reach a climax. The peculiarities of nuclear membrane and linin framework, of nuclear sap and chromatic granules, of chromosomes and nucleoli are too well known to need emphasis. And when to these morphological peculiarities of the nucleus are added its physiological characteristics,—its indispensability in constructive metabolism, regulation and regeneration, its control over cell-differentiation and development, its peculiarities of division, its unfailing continuity from cell to cell and from generation to generation,—it will be seen that this contrast between nucleus and plasma is fundamental. Although germ cells and somatic cells are not essentially unlike, nucleoplasm and cytoplasm are, and there is abundant evidence that germplasm is located in the nucleus, somatoplasm in the cell-body.

4. *Cell Division*

From every point of view our knowledge of organisms has been greatly advanced by the prolonged and extensive study which has been devoted to cell division. The older views as to the origin of cells by "free formation" or *de novo* have been referred to in a previous section (p. 489) and these false views have been responsible for many erroneous theories of heredity and evolution which persist in one form or another to this day. On the other hand the doctrine of Remak (1841) that every cell comes from a preexisting cell by a process of division has been found to be universally true and has greatly influenced almost all lines of biological research.

It was at first supposed that both the cell-body and the nucleus always divided by a process of simple constriction; afterwards it was discovered that the nucleus usually divides in a much more complicated manner and although it is still generally held that the cell-body divides by simple constriction there are evidences that this also is much more complicated than has commonly been supposed.

Neither the nucleus nor the cell-body is a simple, homogeneous structure which may divide equally by simple mass constriction. The nucleus is really a compound structure composed of a larger or smaller number of karyomeres or nuclear units, while the cell-body contains many different structures; a simple mass constriction of the entire cell could not possibly divide all of these equally. Accurate division of a complex cell requires a special mechanism and this is found in *mitosis* or *karyokinesis*.

(*a*) *Mitosis or Indirect Nuclear Division.*—During stages of division there appears in the nucleus a number of deeply staining threads or rods, the chromosomes, while other threads which do not stain readily form a spindle-shaped figure. In most animals and in many of the lower plants there is in the cytoplasm opposite each pole of the spindle a star-shaped figure, the *aster*, with a minute body, the *centrosome*, at its center. The nuclear membrane then dissolves and its contents are set free into the cell body; in place of the nucleus there is left a spindle with the chromosomes gathered around its equator and with the centrosomes and asters at its two poles. Then each chromosome splits lengthwise into two daughter chromosomes and these halves move in opposite directions along the spindle toward its poles, where they unite to form the two daughter nuclei.

This process is known as *mitosis* or indirect nuclear division and its chief significance is found in the fact that each chromosome is divided into daughter chromosomes each of which is identically like the other.

In the meantime complicated movements are taking place in the cell-body outside of the nucleus, which move the mitotic spindle into a definite position in the cell, sort and localize various constituents of the cytoplasm and finally lead to the division of the latter in a plane passing through the equator of the spindle, thus completing the division into two cells.

(*b*) *Persistent Identity of Chromosomes.*—Although the chromosomes constitute so striking a part of a dividing nucleus they usually disappear entirely after division and in their stead one finds only a single nuclear vesicle containing a clear, non-staining fluid or gel, the *achromatin*, imbedded in which are the granules or threads of *chromatin*. Usually no trace of chromosomes can be seen in such a "resting" nucleus.

However the fact that the same number of chromosomes is usually found in every dividing nucleus of any given species, that these chromosomes split lengthwise into daughter chromosomes which then unite to form the daughter nuclei, and that at the next division the same number of chromosomes, having the same shapes and relative sizes, come out of a nucleus as went into it at the preceding mitosis,—these facts early gave rise to the hypothesis that in some way or other the chromosomes preserve their individuality or identity throughout the "resting" stage between successive divisions.

This hypothesis of the "individuality of the chromosomes" has now been verified in a number of cases by actually tracing certain chromosomes into the daughter nucleus and through the "resting" stage until they emerge at the next division as typical chromosomes. It is found that each chromosome absorbs fluid from the cytoplasm and swells up to form a chromosomal vesicle (Fig. 11). These vesicles then unite to form the daughter nucleus and usually the partition walls between vesicles disappear leaving what appears to be a single nuclear vesicle, but in certain favorable objects it can be seen that each chromosomal vesicle persists through the whole of the resting stage and at the next mitosis the chromatin granules within each chromosomal vesicle are drawn together into a chromosome which is in all respects similiar to the one from which that vesicle arose. Probably every chromosome exists as a chromosomal vesicle

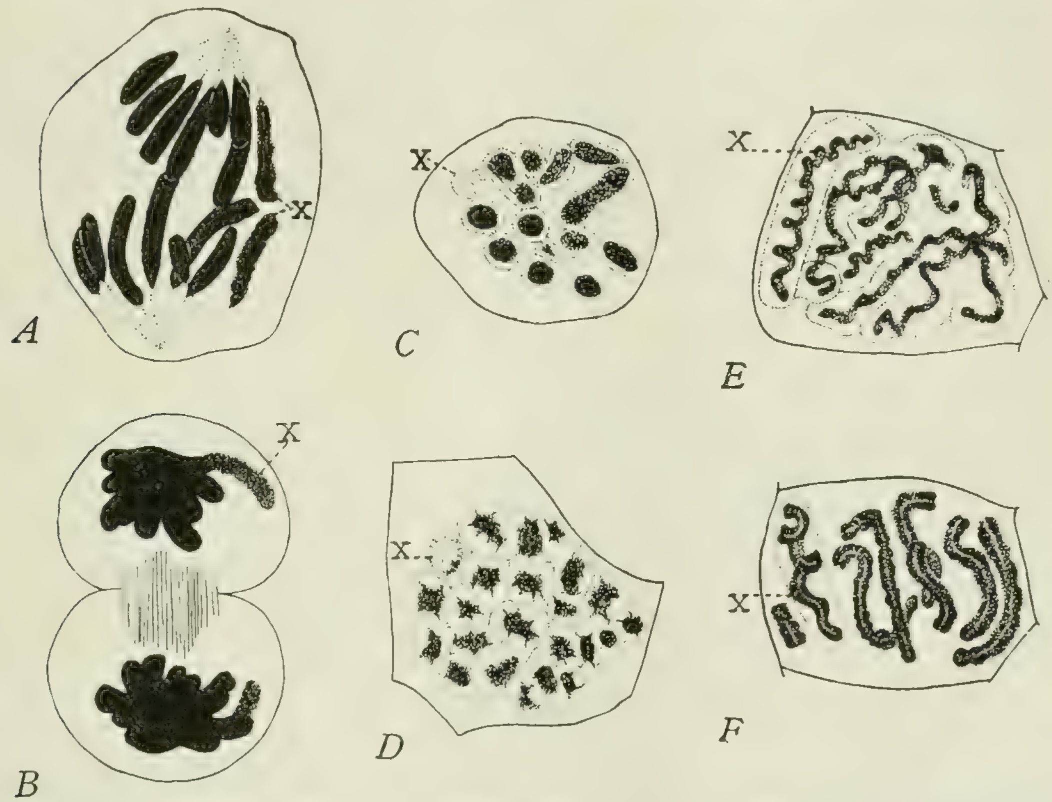

FIG. 11. SPERMATOGONIA OF *Phrynotettix*. *A* and *B*, Middle (metaphase) and late (anaphase) stages of mitosis showing separation of daughter chromosomes, among them the *X* (sex) chromosomes. *C* and *D*, Last stages (telophase) of mitosis passing into the resting nucleus; each chromosome is swelling up into a chromosomal vesicle. *E* and *F*, Early stages (prophase) of next division, showing the reappearence of a chromosome in each vesicle and in *F* the longitudinal splitting of every chromosome. (After Wenrich.)

during the resting stage and as a condensed chromosome during division and thus persists from cell to cell and from generation to generation. Possibly other parts of a cell may preserve indefinitely their individuality or identity, but in the case of the chromosomes this is no longer a mere hypothesis but an established fact.

A chromosome, like any living organism, undergoes many changes in its life cycle without losing its identity. The changes in form and staining reaction which it undergoes in passing from the resting to the dividing stage and *vice versa* indicate that persistent identity does not imply fixity of its entire organization. Nevertheless something, some part of that organization, must persist through all the changes of the division cycle, and it is evident that this is not the deeply-staining portion of the dividing chromosome for in the resting stage this chromatic material may lose its affinity for dyes and coincidently the nucleolus (karyosome) become chromatic, while these changes are reversed at the beginning of mitosis. Likewise in dessicated cells Hickernell found that the chromatic material

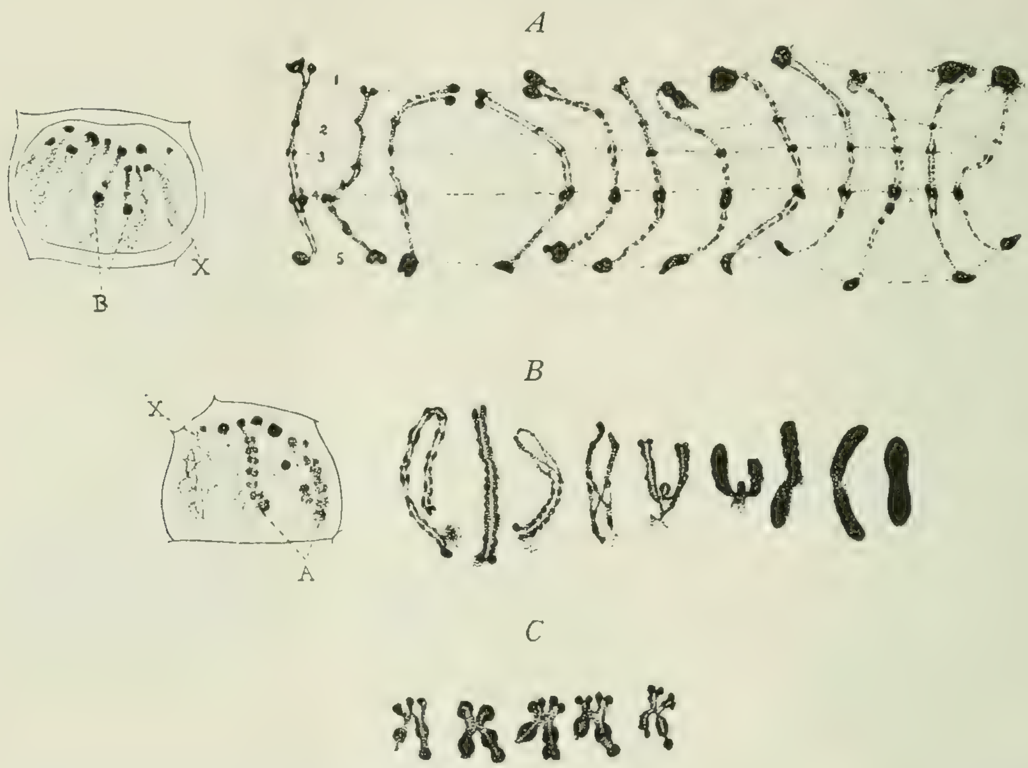

FIG. 12. SYNAPSIS (CONJUGATION) OF CHROMOSOMES IN *Phrynotettix*. *A*, Resting nucleus at left shows indistinct chromosomes, among them chromosome *X* and the pair *B*. At the right are 12 pairs of *B* chromosomes, each from a different animal, showing side by side conjugation of chromosomes of a pair and homologous chromomeres (1, 2, 3, 4) in each pair. *B*, Similar stages in chromosome pair *A*. Some of the chromosome pairs at the right show a secondary longitudinal split and a "crossing-over" of the halves. *C*, Tetrads (bivalent chromosomes) of chromosome pair *B*, formed by shortening and thickening of the chromosome pairs and by the appearance of the secondary split. (After Wenrich.)

moves to the periphery of the nucleus whereas in cells recovering from dessication it goes back into the nucleus. Consequently it seems probable that the persistent part of a chromosome is the achromatic framework or linin in which chromatin is present at certain phases of the cell cycle and absent at others, just as the persistent part of a red corpuscle is the cytoplasmic framework which may or may not contain hæmoglobin.

There is evidence that the chromosomes themselves are compound structures and that just as nuclei are composed of chromosomes or their vesicles, so the latter are composed of smaller units, the chromatin granules or chromomeres. In the formation of chromosomes, the chromomeres appear like beads on a string and in the splitting of chromosomes each chromomere divides into equal halves, and just as the chromosomes are specific bodies each of which preserves its identity, so each chromomere is probably a specific and persistent body. Wenrich has shown that in certain chromosomes of a grasshopper there are specific chromomeres occupying particular positions and that some of these chromomeres preserve their identity throughout the resting stages and are therefore persistent structures (Fig. 12). In all probability further work will demonstrate that every chromomere in a chromosome is a specific and persistent body. Indeed it is probable that chromomeres are much more constant than chromosomes. McClung and his pupils have shown that the number of chromosomes in a given species or in related species may not always be constant, owing to the fact that certain chromosomes may fragment while in other cases separate ones may unite. But whatever the number of chromosomes may be there is apparently a constant number of chromomeres in every species, perhaps even in all closely allied species, and variations in the number of chromosomes are due to the grouping of the chromomeres into a larger or smaller number of chromosomes.

5. *Panmerism*

It is one of the characteristics of organisms and parts of organisms that they are capable of assimilation, growth and division. This is true not only of the larger units of organization but probably also of every unit down to the ultra-microscopic parts of cells and protoplasm. Indeed the larger and more complex units may lose this property while it is still retained by the smaller units. Entire organisms and organs may lose the power of continued growth and division while it is still retained by cells or parts of cells. By this process of growth and division every cell comes from a preceding cell, every nucleus from a nucleus, every chromosome from a chromosome, every chromomere from a chromomere, every gene from a gene, —and in general every vital unit from a preceding unit of the same kind. So far as is known the simpler units always divide equally both in size and quality; this is true of the units composing the nucleus such as chromosomes, chromomeres, genes and probably also of the individual units of the cytoplasm.

But entire cells or groups of cells may divide equally or unequally and the differentiations of development are due mainly to this fact. Such differential divisions of cells are due in the main to different combinations and localizations of units which divide equally and non-differentially, and *in general all forms of differentiation, variation, and evolution are due to different combinations of vital units, whether they be organs, tissues, cells, plastids, chromosomes, chromomeres, genes or subgenes;* just as all forms of chemical compounds are due to different combinations of some 80 chemical elements, and all words, sentences, languages and literatures are the result of different combinations of a small number of letters. However the smaller units of living organization grow and divide equally and not differentially and this property perpetuates the identity of particular kinds of units.

But it is not necessary to assume that everything capable of increasing its own substance is alive. Certainly many substances which are not protoplasm have this power. Ferments which are capable of self-propagation, or substances which produce ferments which in turn are capable of producing those substances, are known. Such reactions are called auto-catalytic and it is probable that many phenomena of reproduction, especially among the smaller units of organisms, are autocatalytic reactions. We do not know whether in such reactions colloidal particles, or molecular aggregates, grow and divide, but this is just what takes place in the parts of cells which are visible with the microscope. These parts of cells are not alive in the sense or to the same extent that the entire cell is; they are incapable of continued independent existence, and it is probably as erroneous to hold that every minute unit of organization is composed of living protoplasm as it would be to regard every brick in a building as a minute house.

B. MECHANISM OF HEREDITY

The mechanism of heredity is to be found in the structure and functions of the germ cells, for everything that is transmitted from one generation to the next must be through the germ cells. The method of studying this mechanism must be by the correlation of particular features of the germ cells with particular phenomena of heredity, in short by the cooperation of cytology and genetics.

1. *Chromosomes and Inheritance Units*

It was pointed out on a previous page that there are many reasons for supposing that the germplasm is located in the nucleus, the somatoplasm in the cell body. Furthermore the chromosomes more nearly fulfill the requirements of an inheritance material than any other constituents of the nucleus. The evidence that the Mendelian factors or genes are located in the chromosomes may be summarized as follows:

(*a*) *General Equivalence of Germplasm and of Chromosomes in Egg and Sperm.*—A study of heredity shows that on the whole offspring inherit as much from one parent as from the other and therefore as many genes must be derived from the sperm as from the egg. But the only substances which are known to come in approximately equal quantities from the two sex cells are the chromosomes. The egg at the time of fertilization contains a relatively large quantity of cytoplasm, yolk and other substances in the cell-body. The spermatozoon, on the other hand, is one of the smallest of all cells and usually its head only enters the egg, leaving the tail and most of the cytoplasm outside. The head of the spermatozoon consists almost entirely of a condensed nucleus in which is the characteristic number of chromosomes. In the egg nucleus also this characteristic number of chromosomes is present. The egg and sperm nuclei come together within the egg and their chromosomes mingle but do not fuse together nor lose their identity. The chromosomes which come from the egg and those from the sperm are not only equal in number and size but are also alike in shape so that in every fertilized egg there are two sets of similar chromosomes, one set from the egg and the other from the sperm. The chromosomes are the only portions of the male and female germ cells which are approximately equal in volume and it is therefore probable that they are the seat of the inheritance material.

(*b*) *Equal Distribution to all Cells.*—Since inherited characters of one or the other parent may appear in every part of the bodies of offspring, it must be that inheritance units from the two parents are distributed equally to every cell. So far as known the only portions of the egg and sperm which are distributed equally to every cell of the developing organism are the chromosomes. At the first division of the fertilized egg and at every subsequent division each chromosome divides equally and its halves go into the two daughter cells. Therefore every cleavage cell, and ultimately every cell of the adult body comes to contain one full set of chromosomes from the egg and another set from the sperm. Since the chromosomes are the only portions of the egg and sperm which are known to be distributed equally to every cell, it is probable that they contain the inheritance factors.

(*c*) *Conjugation and Reduction of Maternal and Paternal Chromosomes.*—In the last stages of the formation of the germ

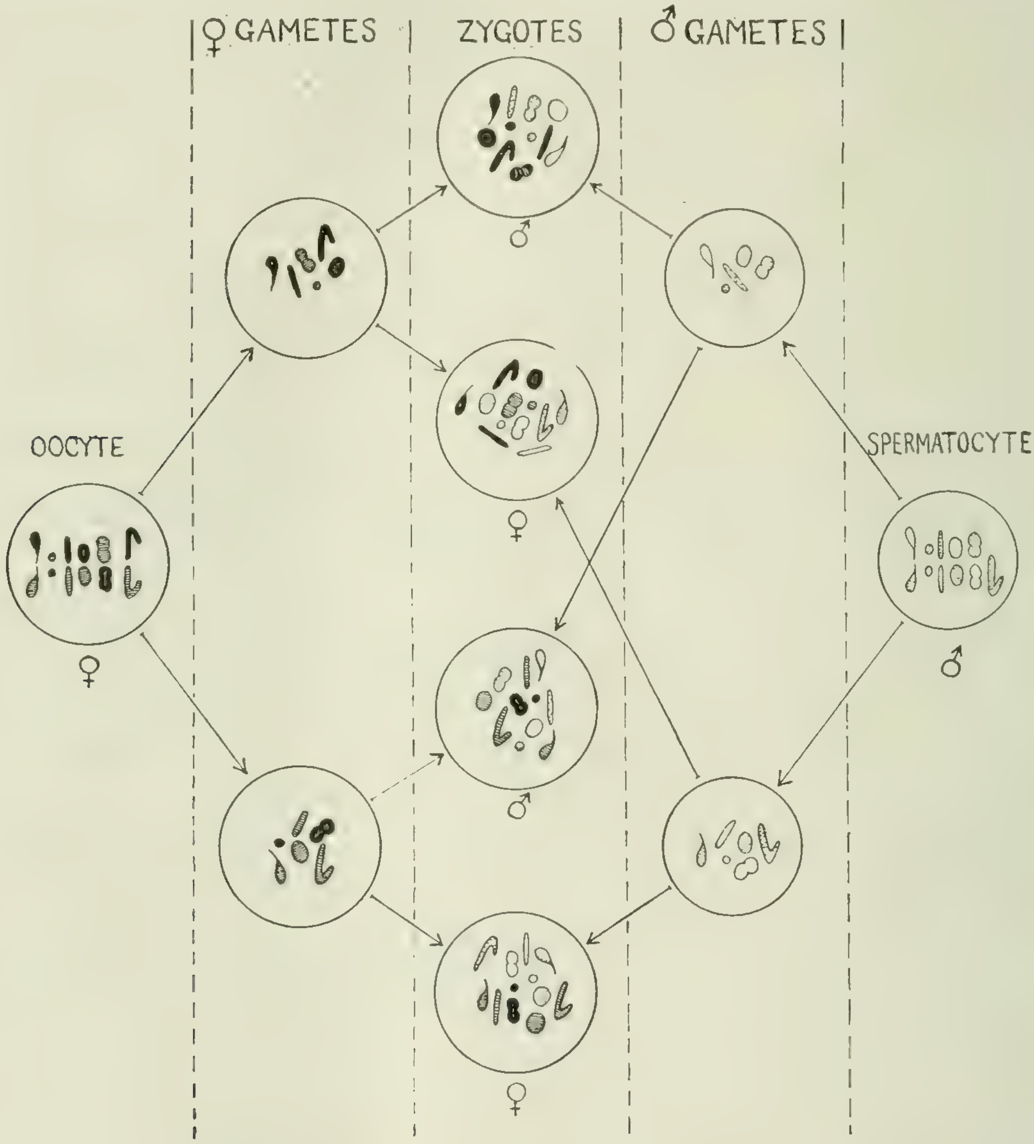

FIG. 13. DIAGRAM SHOWING SOME OF THE POSSIBLE DISTRIBUTIONS OF CHROMOSOMES OF GRANDPARENTS TO GRANDCHILDREN. Chromosomes of paternal grandfather unshaded, of paternal grandmother stippled, of maternal grandfather with cross lines, of maternal grandmother black. The sex chromosomes are *J*-shaped, a pair being present in the female and a single one in the male. In the oocyte and spermatocyte synaptic pairs of homologous chromosomes are shown separating so that the gametes contain only one of each pair. By the union of gametes to form zygotes the double number is restored.

cells the two sets of parental chromosomes temporarily unite, and in general long chromosomes pair with long ones, short ones with short ones and those of peculiar shape with others of similar shape; in short the members of each pair are homologous chromosomes. This process is known as *synapsis* or the conjugation of the chromosomes, the pairs are called synaptic pairs or bivalent chromosomes; and in some cases it can be demonstrated that one member of each pair comes from the father, the other from the mother (Figs. 12, 13, 15, 16).

In all ordinary divisions every chromosome splits into two and the halves go into the daughter cells, but in one or the other of the last two divisions leading to the formation of the germ cells, the synaptic pairs separate, whole chromosomes going into the daughter cells. By the separation of whole chromosomes in this division the germ cells come to contain only one half as many chromosomes as the other cells of the body. The full number of chromosomes is the diploid number ($2n$), the reduced number the haploid ($1n$) and the division by which this reduction is effected is known as the "reduction division." On the other hand ordinary divisions, in which each chromosome splits and the daughter cells contain as many chromosomes as the mother cell, are known as "equation divisions."

Since one chromosome of each synaptic pair is from the father and the other from the mother and since these chromosomes separate freely in the reduction division, that is each member is free to move to either pole of the mitotic spindle, it follows that each germ cell or gamete contains one full set of chromosomes, some of which are from the father and others from the mother, but only one chromosome of each pair is found in any gamete (Fig. 13).

The correlation between these cytological facts and the phenomena of heredity are very striking. All hybrids carry two sets of factors, derived from the two parents, but in the formation of the gametes these factors separate so that every germ cell is pure with respect to any character. In this respect the factors, which are invisible, behave exactly as do the chromosomes which are easily seen. Indeed it would be impossible to invent a more perfect mechanism for the segregation of Mendelian factors than is found in the union of maternal and paternal chromosomes into synaptic pairs and their subsequent separation in the reduction division. This complete parallelism between the behavior of the chromosomes and of the inheritance factors is convincing evidence that the factors are located in the chromosomes (Figs. 14, 15).

(*d*) *Doubling of Chromosomes and of Factors in Fertilization.*—Finally in the union of male and female gametes, each having the reduced or haploid number of chromosomes, the somatic or diploid number is restored. The chance combination of chromosomes in fertilization is identically like the chance combinations of inheritance factors, and both yield the same Mendelian ratios. Mendelian segregation and recombination of factors is exactly parallel to the reduction of chromosomes in gametogenesis and their union in fertilization. In every respect chromosomes may stand as the visible symbols of factors (Figs. 14, 15). It is highly probable therefore that the factors are located in the chromosomes.

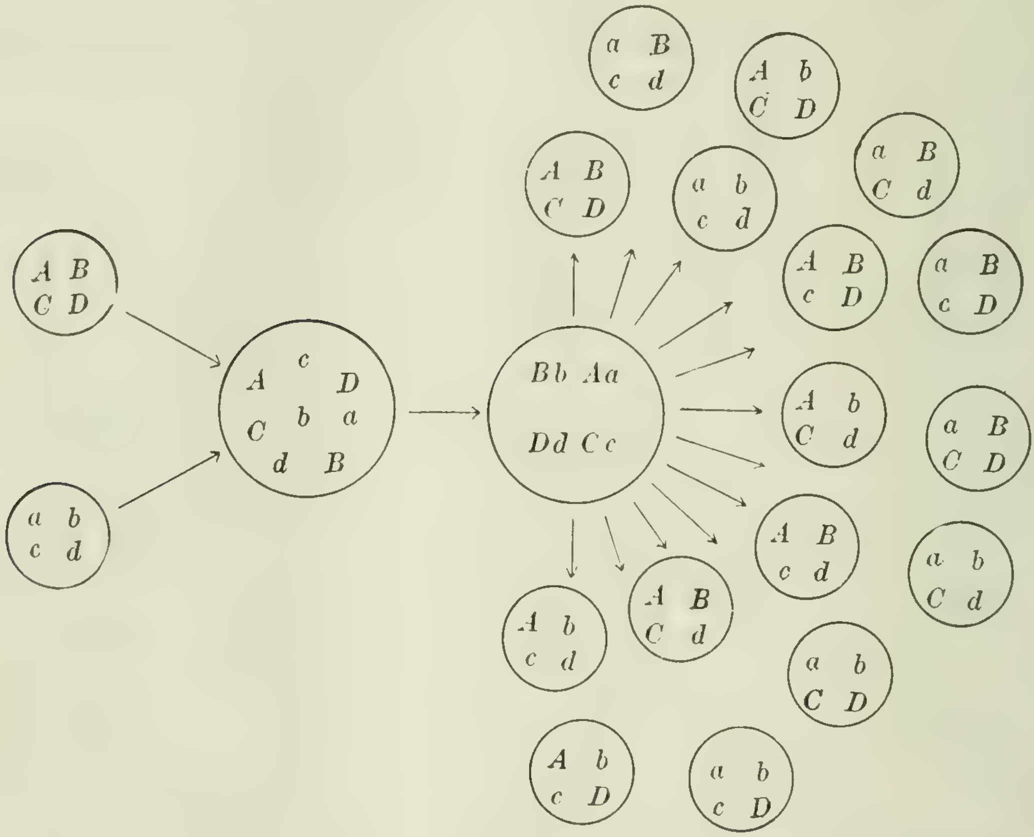

FIG. 14. DIAGRAM SHOWING UNION IN FERTILIZATION, CONJUGATION IN SYNAPSIS AND SEGREGATION IN FORMATION OF GAMETES of Factors *A, B, C, D* of the egg and *a, b, c, d,* of the sperm. (After Wilson.)

(*e*) *Sex-Determination and "Sex-Chromosomes."*—Still further evidence that the chromosomes are the seat of inheritance factors is found in the relation of some of these bodies to sex-determination.

The cause of sex has been a subject of speculation and theorizing for hundreds if not thousands of years, but within the last fifteen years it has been discovered that at least the initial cause of the differentiation of the two sexes is inherited, although there may be many other causes which are environmental. In this respect sex does not differ from any other inherited character; many causes both hereditary and environmental are involved in the *development* of any inherited character; all that is implied in saying that any character is *inherited* is that its initial differential is transmitted through the germ cells.

In this sense it is known that in many animals and plants sex is inherited as a Mendelian character, one sex being homozygous and the other heterozygous for this character and that consequently the heterozygous sex forms two sorts of germ cells, the homozygous but one and the chance combination of

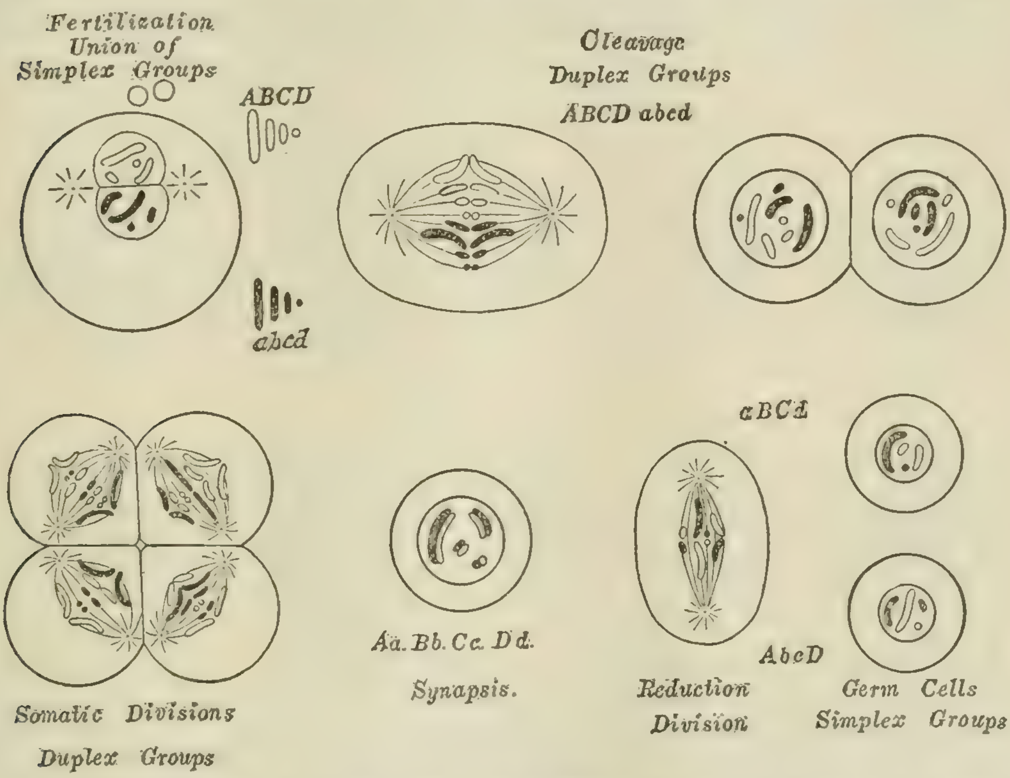

Fig. 15. Diagram of Union of Chromosomes of Egg and Sperm in Fertilization, their Conjugation in Synapsis and Segregation in Formation of Germ Cells, corresponding to the factors shown in Fig. 14. (After Wilson.)

these germ cells yields equal numbers of homozygotes and heterozygotes, which fact explains the numerical equality of the two sexes.

In all such instances we have a plain Mendelian case of the crossing of a heterozygous with a homozygous form in which one half of the offspring are homozygous and the other half heterozygous, as shown in the following scheme:

Female (homozygous) produces Eggs of one type....... = ♀ ↖ — ↗ ♀
Male (heterozygous) produces Sperms of two types...... = ♀ ╱ — ╲ ♂
All possible crosses result in.......................... = 2♀♀ : 2(♀)♂

or the ratio of males to females is 1 : 1.

In the spermatogenesis of certain insects it had been observed that there was an odd number of chromosomes and in synapsis when homologous maternal and paternal chromosomes unite in pairs one of these chromosomes was left without a mate; it was therefore called the "odd" or "accessory" chromosome. In the reduction division when the two chromosomes of a pair separate the odd chromosome went entire to one pole of the mitotic figure and there was no corresponding chromosome at the other pole; consequently, one of the two gametes formed by this division had one chromosome more than the other and two types of spermatozoa were formed in equal numbers,—one type with and one without the "odd" chromosome (Fig. 16).

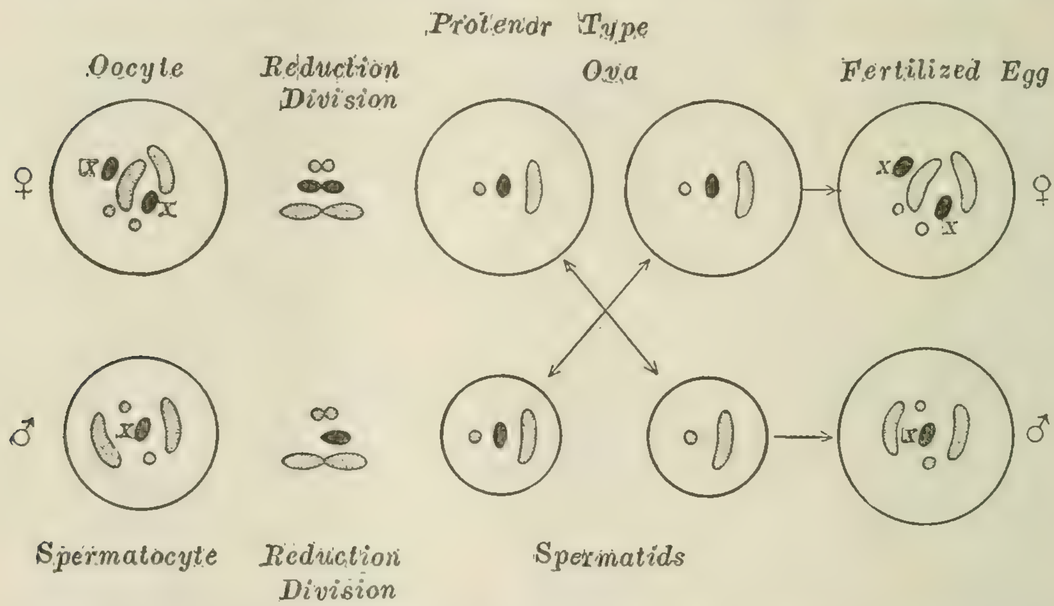

FIG. 16. DIAGRAM OF CHROMOSOMAL DETERMINATION OF SEX IN *Protenor* (XO TYPE). The oocyte contains 6 chromosomes, 2 of them being sex chromosomes (X), the spermatocyte contains 5, there being only 1 X; after reduction each egg contains 1 X and 2 ordinary chromosomes; half of the spermatozoa contain 1 X and the other half lack it; if an egg is fertilized by a sperm with an X a female results, if by one without the X a male is produced. (After Wilson.)

Since the 1:1 ratio of these two types of spermatozoa corresponds to the usual sex ratio, McClung suggested that this "odd" chromosome was a sex determinant. Wilson and Stevens then found that all eggs contain this "odd" chromosome, which was therefore called the "sex" chromosome, or the "X" chromosome, and that any egg fertilized by a sperm containing this chromosome produced a female, whereas if fertilized by a sperm without it a male was produced, as is shown in the following diagram:

Chromosomal Constitution of Male (♂) Zygote XO, of Gametes. X ↓↘↙↓ O
of Female (♀) " XX, " " . X X

All posible combinations of these Gametes (indicated by arrows) 2XX (♀) : 2XO (♂)

Later Wilson and Stevens discovered that in the males of certain other insects the "odd" chromosome had a mate which was small or rudimentary and which they called the "*Y*" chromosome. Consequently the sex chromosomes of the male were in these cases *X* and *Y*, while those of the female were *X* and *X* and the chance combinations of the gametes formed by these animals yielded equal numbers of the combination *XY* (♂) and *XX* (♀) (Fig. 17).

At present it is known in more than one hundred species of animals and plants that with respect to the sex chromosomes two types of spermatozoa occur and but one type of ova, that

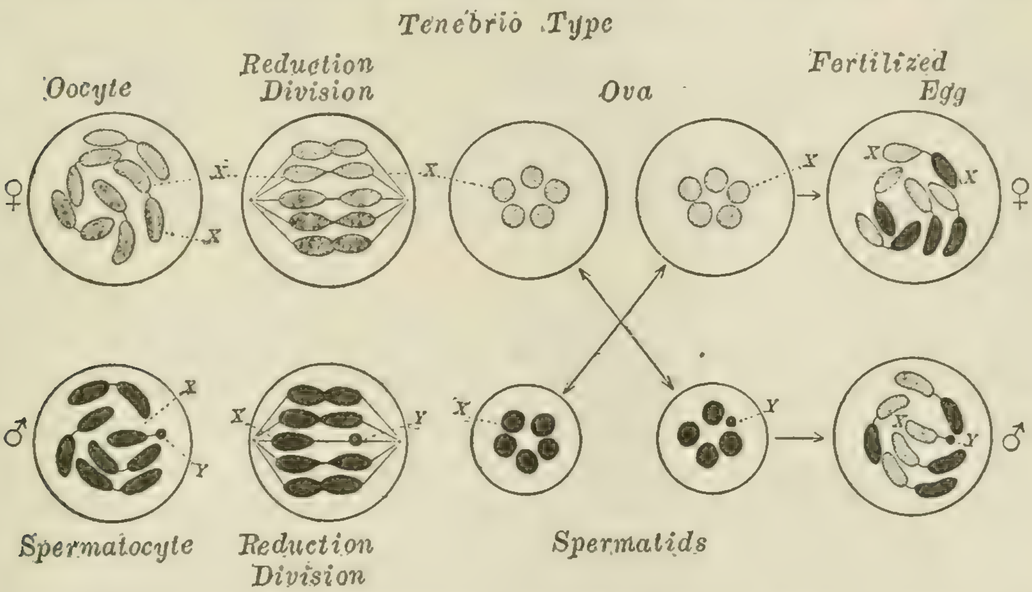

FIG. 17. DIAGRAM OF CHROMOSOMAL DETERMINATION OF SEX IN *Tenebrio* (*XY* TYPE), showing 5 synaptic pairs of chromosomes (there are actually 10 pairs). In the oocyte the sex chromosomes (*XX*) are equal in size and after reduction each ovum contains 1 *X*; in the spermatocyte these chromosomes are unequal (*XY*) and after reduction half of the spermatozoa contain a large *X* and half a small *Y*; sex is determined by the chance union of one or the other of these types of spermatozoa with the single type of ova.

eggs fertilized by one type of sperm produce males and by the other type females. In a few cases among Lepidoptera and birds there is evidence that the female is heterozygous for sex, the male homozygous, and that correspondingly two types of ova are produced and but one type of spermatozoa; but this does not affect the general principle that sex is determined by the chance union of gametes bearing particular sex chromosomes.

This correlation between the presence or absence of a whole chromosome and of a developed character such as sex, is the only case of the kind that is known and more than anything else it has served to prove that the chromosomes contain the Mendelian factors. The absence of a whole chromosome is plainly visible under the microscope, whereas the absence of a single factor or gene from a chromosome would never have been seen. These fortunate cases in which the male lacks a whole chromosome give ocular proof of the chromosomal theory of heredity.

Environmental Influences.—It should be said that a number of apparent exceptions to the chromosomal determination of sex are known. In some of these cases environmental conditions change the usual 1:1 sex ratio or lead to the development of "intersexes" which are more or less intermediate between males and females. Departures from the normal sex ratio are sometimes due to the early death of one type of gametes or zygotes; "intersexes" may be caused by a balancing of male-producing and female-producing factors in the zygote, or of conflicting genetic and environmental factors in development. These cases illustrate the necessity of distinguishing between the hereditary determination of sex and its ontogenetic development.

Probably in every case these apparent exceptions to the chromosomal determination of sex may be explained in conformity with that theory; in any event this theory is now so well established in so many different cases that it may be accepted as the usual if not the only method of sex determination. But this means only that the initial factors for sex *determination* are carried in a particular chromosome. Doubtless there are many other factors in the *development* of sex, some of which are germinal and others environmental.

The male or female condition may be regarded, therefore, as the result of the dominance of male-determining or female-determining factors, and the condition of "intersexes" as the result of the partial dominance of one or both of these factors. This applies of course to the primary sex characters, such as ovaries and testes, and also to secondary characters which are associated with one or the other sex, such as peculiarities of size, color, hair or feathers, mammary glands, voice, instincts and habits, etc. The full development of these secondary sex characters is usually limited to one sex or the other; they are known as *sex-limited* characters and their development is dependent upon the dominance of the male-determining or the female-determining factors, whether those factors be hereditary or environmental.

Sex-linked Characters.—Another class of characters which Morgan has called *sex-linked* are inherited in the same way that sex itself is and for the reason, as he has proved, that their genes are located in the sex-determining chromosome. These characters may have nothing to do with sex itself but their genes are linked with those of sex. Morgan has found a large number of such sex-linked characters in the pomice fly, *Drosophila melanogaster*, among them eye-color, body-color, wing characters, etc. Other well-known cases are Daltonism or color blindness and hemophilia or slow clotting of blood in man.

Such sex-linked characters are like recessive ones in that they do not develop when balanced by a normal allelomorph. Consequently they do not develop in females unless they are inherited from both parents, their genes being present in both

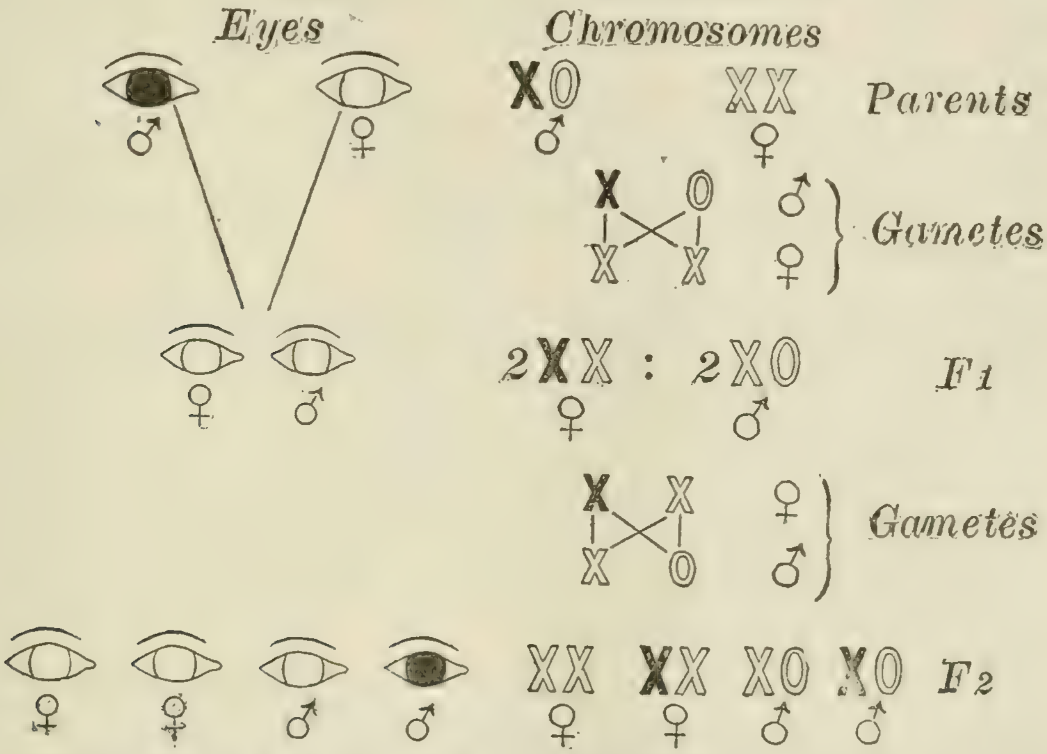

FIG. 18. DIAGRAM OF SEX-LINKED INHERITANCE OF COLOR-BLINDNESS (DALTONISM). A color-blind male (here black) transmits his defect to one half of his grandsons only. The corresponding distribution of the sex chromosome containing the gene for this defect is shown on the right. (After Morgan.)

X chromosomes, whereas in males they are always inherited from the mother only since the single *X* chromosome of the male always comes from the mother. All the sons of a color-blind father and normal mother are normal since the single *X* chromosome which they have comes from the mother and carries the gene for normal vision. All the daughters of such a cross appear normal, although carrying the paternal gene for color-blindness, since they also have from their mother the gene for normal vision. Half of the germ cells of these daughters carry the gene for color-blindness, half for normal vision and if one of the former kind is fertilized by a male-producing sperm it gives rise to a color-blind male since in this case the gene for color-blindness is not balanced by a normal allelomorph; consequently half of the sons of the F_2 generation will be color blind (Fig. 18).

(*f*) *Abnormal Distribution of Chromosomes and Factors.* —Experimental evidence that the chromosomes are the seat of inheritance factors is found in the correlation between the abnormal distribution of chromosomes and the development of abnormal characters in the embryo or adult. An abnormal distribution of chromosomes to the cleavage cells may be caused in a variety of ways but one of the least injurious methods of accomplishing this is by causing two spermatozoa instead of one to enter an egg. In such doubly fertilized eggs Boveri discovered that different cleavage cells receive a different number of chromosomes and in general those cells which receive the largest number develop most typically, while those which receive a small number develop atypically. By a skillful analysis Boveri proved that normal development depends not so much upon the absolute number of chromosomes in a given cell as upon a complete set of all the different kinds of chromosomes, and when a complete set was not present certain characters were lacking in development. By this means he showed that different chromosomes of a set differ in hereditary value, as, for example, the fingers of a hand differ from one another, and that two chromosomes of one kind could not make up for the lack of one of another kind, any more than two thumbs could make up for the loss of a little finger.

A still more detailed correlation between the presence or absence of a particular chromosome and the presence or absence of particular characters in the developed organism has been described by Bridges (1916). In his study of the pomice fly, *Drosophila melanogaster*, he found that the occasional appearance (1 in 1700) of a matroclinous daughter or patroclinous son was due to the fact that the *XX* pair of chromosomes fail to separate in the reduction division of the egg so that both *XX*'s are included in the egg (Fig. 20, *C*) or both are extruded in the polar body, or the *XY* pair fail to separate in the reduction division of the sperm so that one sperm may have both and another lack both of these chromosomes. This phenomenon he calls "non-disjunction" and it results in the production of matroclinous daughters or patroclinous sons, and in many other irregularities of inheritance which follow precisely the abnormal distribution of these chromosomes. A patroclinous son is the result of the fertilization of an *O* egg by an *X* sperm; such an XO son is sterile whereas the normal XY son is not, thus showing that the chromosome Y has some function though apparently it does not contain any of the genes; fertilization of an O egg by a Y sperm produces a combination (YO) which is non-viable. Fertilization of an XX egg by a Y sperm produces a matroclinous daughter (XXY), whereas fertilization of an XX egg by an X sperm produces a combination (XXX) which is non-viable. These relations are shown schematically in the accompanying diagrams (Fig. 19).

Finally the most notable correlation between abnormal distribution of chromosomes and the development of abnormal

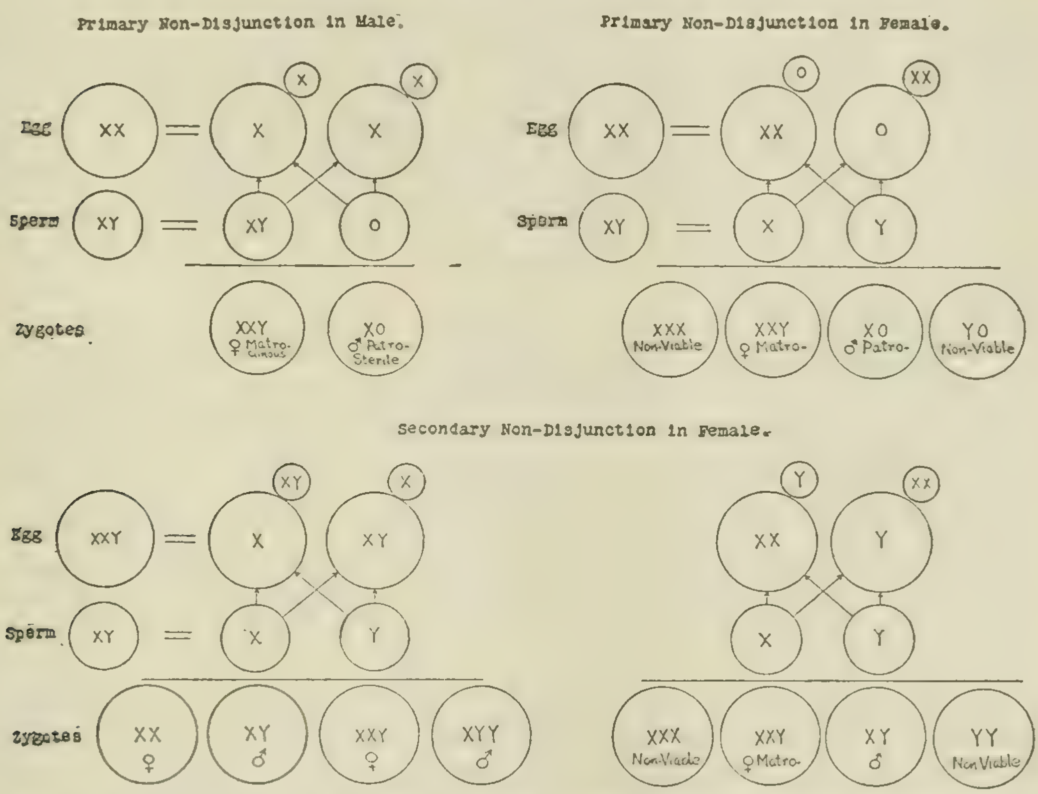

FIG. 19. DIAGRAM OF NON-DISJUNCTION OF SEX CHROMOSOMES (BRIDGES) IN THE MATURATION OF THE EGG AND SPERM AND THE RESULTING TYPES OF ZYGOTES.

characters has been found by Morgan in gynandromorphs or sex-mosaics of *Drosophila* in which one portion of the body has the characters of the male and another those of the female. Such sex-mosaics are evidently due to the fact that in the ordinary somatic cell-divisions the pair of XX chromosomes in the female or of XY chromosomes in the male do not go into every daughter cell but are so distributed that two Xs (female constitution) occur in some cells and one X (male constitution) in other cells.

All of these cases of abnormal distribution of chromosomes coincide exactly with the subsequent abnormal distribution of characters in the developed animal and they prove that the inherited factors for these characters are located in the chromosomes.

(*g*) *Linkage of Characters and Chromosomal Localization.* —Finally the study of characters which are linked together in heredity, joined with the study of the chromosomes and their distribution in the maturation and fertilization of the germ cells, has not only confirmed the chromosomal theory of heredity but has also shown that certain chromosomes carry the genes for certain characters and has even indicated the relative positions of different genes in the chromosomes.

In higher animals and plants the number of chromosomes is small as compared with the number of their Mendelian factors, and therefore if these factors are located in the chromosomes each must contain several of them. Since chromosomes generally preserve their identity or individuality the factors which they contain should be linked together and developed characters should be inherited in groups corresponding in number to the different chromosomes.

It has been known for a long time that certain characters are correlated so that they usually go together although they may have no evident dependence upon one another. Thus Darwin mentions the fact that male albino cats with blue eyes are usually deaf and have defective teeth. Many other cases of the association of peculiar characters were reported by earlier and later observers but the causes of such correlations were wholly unknown.

Since 1910 Morgan and his associates have discovered more than one hundred new characters, or mutations, in the pomice fly, *Drosophila melanogaster*, which are linked together into four groups, corresponding to the four pairs of chromosomes in this species. Up to 1916 they had located in the first group 47 different characters, in the second 27, in the third 22 and in the fourth 2.

Corresponding with the number and size of these groups there are four pairs of chromosomes in *Drosophila*, three of which are large and one is very small (Fig. 20). The sex chromosomes (*XY* in the male, *XX* in the female) constitute one of the large pairs and the genes of the characters which are sex-linked are located in these chromosomes; the genes of the second and third groups of characters are presumably in the other large chromosomes, while the fourth group of only two characters probably have their genes in the very small chromosomes. If this interpretation is correct, linkage is due to the grouping together of certain genes in certain chromosomes, there are as many groups of characters as there are pairs of chromosomes and as long as the chromosomes preserve their individuality the linkage of genes in the chromosomes and of characters in the developed organism will persist.

"Cross-Overs."—But linkage of inherited characters is not quite so simple as this statement would indicate for an extensive study of this phenomenon in *Drosophila* has shown that while characters are usually inherited in the same groups this is not always true. For example, Morgan has found that when a female fly with white eyes and yellow wings is crossed to a male with red eyes and gray wings all the sons are yellow and have white eyes while all the daughters are gray and have red eyes, but when these latter are crossed 99 per cent. of the offspring show the same linkage of the colors yellow-white, gray-red, but in 1 per cent. the linkage is yellow-red, gray-white.

FIG. 20. CHROMOSOMES (DIPLOID NUMBER) OF *Drosophila melanogaster*. *A*, Female with 2 *X* chromosomes; *B*, Male with 1 *X* and 1 *Y*; *C*, Matroclinous female resulting from non-disjunction of the 2 *X* chromosomes of the egg. (After Morgan.)

This interchange of characters in the two groups, or "cross-over" as Morgan calls it, may be explained by assuming that there has been an interchange of genes between the two sex chromosomes of the female; "cross-overs" do not occur in the male of *Drosophila*. Janssens has found that when the paired chromosomes lie side by side in synapsis they sometimes twist around each other and in their subsequent separation each chromosome sometimes breaks at the point where the two cross and a portion of one chromosome is thereafter joined to the other one. In this "chiasmatype" of Janssens we have a relatively simple explanation of the interchange or "cross-over" of genes and consequently of the breaking up of old groups of characters and the establishment of new ones. Similar regrouping of characters takes place in each of the other three groups of *Drosophila* and can be explained in the same way (Fig. 21). If chromosomes of a pair are twisted round each other at more than one place and are then broken at these points we get double or multiple crossing-over and a corresponding re-grouping of genes and of characters. Unless a pair of chromosomes are very tightly twisted two cross-overs will not occur near together and in general the farther apart points are in a chromosome the more likely is a cross-over to occur.

All genes which are linked to each other lie in the same chromosome and Bridges (1914) has shown that the farther apart in a chromosome any two genes lie the greater is the

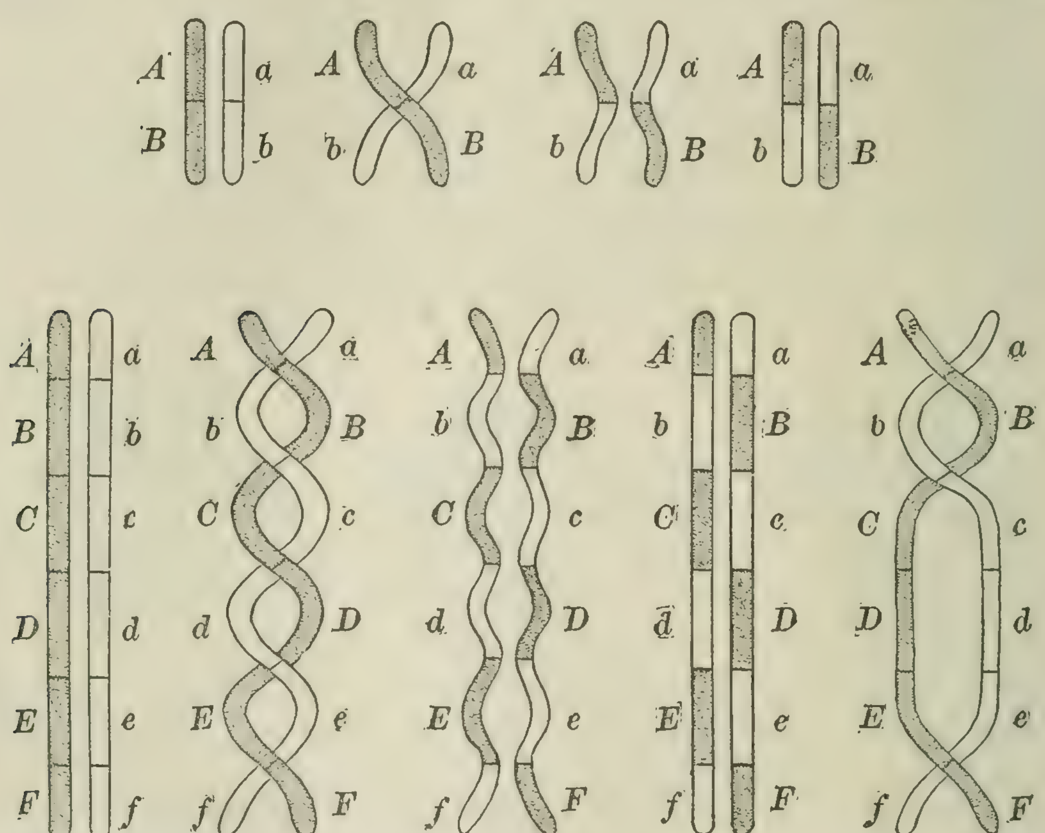

FIG. 21. DIAGRAM OF THE PROBABLE MECHANISM OF "CROSSING-OVER." Pairs of homologous chromosomes, one from the father the other from the mother, are shown in synapsis; on the left they lie parallel to each other and when they separate they remain as they were before union; in the second column they are shown crossing each other one or more times; in the remaining figures are shown the results of the chromosomes breaking at the points of crossing, thus interchanging sections of the two chromosomes. Letters indicate *loci* of homologous genes in the two chromosomes of a pair. (After Wilson.)

amount of crossing-over between them. Morgan takes 1 per cent. of crossing-over as the "cross-over value" and in general this may be used as the unit of distance between genes in the same chromosome. If cross-overs between two genes take place only in one case out of a hundred (1 per cent.) the genes are supposed to be separated by only one (1) unit of distance; if in thirty cases out of a hundred (30 per cent.) they are separated by thirty (30) units, etc. And when the relative numbers of all cross-overs are considered it is possible to construct a "map" of the chromosomes, as Morgan has done, showing the relative positions and distances apart of all the genes concerned.

Such a map represents only an approximation to the truth since certain conditions may change the percentage of cross-overs; thus Sturtevant has found that "factors for crossing-over" may be present in certain cases which modify the expected percentages, and Plough has shown that crossing-over may be increased by high temperatures, and that it takes place only in the *early oocyte* stage when the chromosomes are fine threads. Nevertheless these modifications of the percentages of cross-overs do not appear to invalidate the calculations as to the relative positions of genes in a chromosome.

Castle (1919, 1920) maintains that Morgan's evidence does not support the hypothesis of the linear arrangement of genes in a chromosome and he attempts to show that an arrangement of genes in three dimensions of space around the chromosomes is a more likely hypothesis. Without entering into the details of his argument it may be said that the longitudinal splitting of chromosomes, the equal division of genes, and the union of chromosome pairs in synapsis during the slender thread stage seem to admit of no other explanation than a linear arrangement of genes in the chromosome.

This work of Morgan and his associates on the localization of genes is in all respects the most remarkable work which has ever been done in this field; for the first time it gives us a detailed picture of what Weismann called the "architecture of the germplasm"—for the first time it assigns to different genes "a local habitation and a name."

(*To be continued*)

A GRAPHIC METHOD OF MEASURING CIVILIZATION, AND SOME OF ITS APPLICATIONS

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IN his interesting book, "Civilization and Climate" (Yale University Press, 1915), Dr. Ellsworth Huntington has essayed to map the degrees of civilization of the whole world, and the United States in particular, and to correlate these with certain rather complex climatic factors which he had ingeniously worked out. He used several different methods for measuring civilization, but relied chiefly on a sort of composite picture of the opinions of fifty correspondents of wide experience in various parts of the northern hemisphere, supplemented by his own observations in many lands, and some independent statistical data.

Each collaborator was asked to assign a sort of percentage rating in the scale of civilization to each of the principal geographical unit areas of the world (185 in number), and the results were then averaged and mapped. These individual opinions were doubtless based on general impressions of characteristics not easily weighed or measured, and the emphasis given to each characteristic naturally varied with different collaborators. One of them took the trouble to tabulate his estimates for a few countries in considerable detail, mentioning such attributes as initiative, inventiveness, ability to carry out large projects, attention paid to education, hygiene and morality, and appreciation of the beauties of nature, art, and literature.

For the United States alone (presumably because similar statistics were not available for many other countries) Dr. Huntington supplemented the opinions of his correspondents with statistics of mortality, illiteracy, school attendance, and distinguished persons,[1] and suggested the possibility of using for the same purpose criminal records, railway mileage, postal business, and manufacturing. For comparing the efficiency of whites and negroes in one of the early chapters he set forth the results of certain psychological tests of school children, earn-

[1] An interesting early contribution to this subject is an article by Hon. Henry Cabot Lodge on the distribution of ability in the United States, in the *Century* (20: 687–694) for September, 1891.

ings of workers in specified industries, and certain census data for the farms of the two races in selected groups of states, some northern and some southern.

The final results in each case agree reasonably well with each other and with what a well-informed reader perusing the book for the first time might expect, as well as with the climatic factors used. But in the discussion of the civilization maps the reader is left in doubt as to whether any or all of the fifty collaborators took into consideration the whole population of each country or only the upper strata.

One would not have to go very far afield to find communities in which the adult population is relatively homogeneous with respect to the characters that make up civilization, analogous to a prairie in which most of the mature plants are of about the same height, and others with considerable numbers of both celebrities and "undesirable citizens," a condition analogous to a forest with tall trees, lowly fungi, and various intermediate forms.[2] Every large city has its cultured aristocracy and its slums, and a person relying on statistics of illiteracy, pauperism and crime for measures of civilization might rate such a city lower than a thriving rural community, while one looking only at the achievements of the most prominent citizens would put the city the higher. In some of the southeastern states a century ago about half the population consisted of illiterate slaves, but the "quality folks" gave these same states a higher standing in the eyes of the world than the more newly settled middle western or north central states, with their then much more homogeneous population.

It is evident therefore that in order to get a fair measure of civilization we must eliminate personal opinions as far as possible and find one or more rational tests that can be applied to the whole population or the greater part of it; or better still, instead of merely taking averages, devise curves to show the range of variation in each community or group studied. For most such data we must look to the government census reports, but some are more readily obtainable from other sources, and some not at present available at all except for a few small groups may possibly be returned by future censuses.

The statistics that may be used as criteria of civilization might be divided roughly into two classes, namely, institutional and individual. The former are obtained from corporations, organizations, public officials, etc., and include such matters as

[2] See article on plant sociology in the SCIENTIFIC MONTHLY (4: 456–460) for May, 1917.

aggregate and per capita wealth; manufacturing, banking and insurance; railway mileage, number of newspapers, telephones, automobiles, libraries, etc., per capita or per square mile; church membership, school attendance, pauperism and crime.[3] Individual statistics are based on inquiries made of or about all individuals (or at least all adults, voters, or heads of families), and may include, among other things, number of persons per unit area, distance of residence from birthplace, age, marital condition, education, and occupation. (Wealth and church membership could indeed be ascertained from individuals, but our census has never been so inquisitorial.) The statistics of agriculture occupy an intermediate position, for the average farm is commonly a one-family institution.

Almost any of the kinds of institutional statistics could be used as a rough measure of civilization, but different kinds might conceivably give quite divergent results. Some very significant data about the civilization of rural districts can be obtained from agricultural statistics, such as the value of farm buildings, the proportion of farm land that is cultivated, the value of crops per acre, etc., but that tells us nothing about conditions in cities, and need not be considered further at present.

Some of the individual statistics, such as those of age and marital condition, do not vary much with the progress of civilization, while others, like illiteracy, give us only one average (or as many averages as there are groups used), without telling how far any individuals depart from that average. If, however, we have criteria in which each individual is given a rating, and the number of persons between any two points on the scale is known, we can look at the matter in a two-dimensional way and construct characteristic curves for each community or group. The census has long been giving us information of this sort about the ages of the population, but as just stated that is of little or no service in measuring civilization, the age curves for all sufficiently large populations being very similar.

The two most promising criteria for making civilization curves seem to be education and occupation; but unfortunately the treatment of these in our censuses hitherto has not been very satisfactory. About the only inquiry on existing census schedules about the education of the adult individual is whether or not he can read and write. It would seem perfectly feasible and very desirable for the census demographers to recognize

[3] It has been suggested, though perhaps not altogether seriously, by some chemists that the amount of soap or of sulphuric acid used by a nation is a pretty good measure of its civilization.

several grades of education instead of only two, separating those who have been through high school or college from those who have not, and so on, or simply to ascertain how many years of schooling each person has had. If errors were made by the enumerators they would balance to a considerable extent in the final summing up, and even if many individuals remained wholly unclassified as to education, significant ratios could still be worked out from the returns for the others. The results of such an inquiry could of course be further segregated according to race, sex, and age, like the present illiteracy data, or restricted to adults if desirable.

As far as occupation is concerned, recent censuses classify workers minutely enough by industries, but not very satisfactorily by grades of work, so that one would have trouble in determining from the returns the number of idlers, unskilled and skilled laborers, clerks, foremen, proprietors, etc., in a given community. There should be no special difficulty, however, in preparing schedules that in addition to classifying the workers by industries as heretofore would put each individual into a certain grade. If we fix the number of grades at ten for convenience they might be divided as follows:

0. Persons who are a burden to society, such as criminals, imbeciles, mendicants, vagrants, and paupers.

1. Unemployed but harmless persons, such as children, students, invalids, gentlemen of leisure, and aged people.

2. Unskilled laborers, who work mostly in gangs, under more or less constant supervision, with a minimum of responsibility.

3. Here may be put three fairly distinct groups, which are of approximately equal rank, but could be separated if more than ten grades were used. First, men who require no more education than the unskilled laborers, but have more responsibility, and work much of the time alone, and thus have opportunity to cultivate their powers of observation and develop resourcefulness. *E.g.*, woodsmen, fishermen, farm hands, miners, cowboys, teamsters, boatmen, trainmen. Second, semi-skilled laborers, who require usually a few weeks to become proficient in their work, such as factory operatives, motormen, chauffeurs, locomotive firemen, and house-painters. Third, persons who have some responsibility, financial or otherwise, but little or no authority other than that involved in keeping order or guarding property, and do not need much education. Examples are clerks of various kinds, agents, salesmen, small merchants, policemen, city firemen, soldiers, and janitors.

4. Skilled laborers, who have learned a trade by a period of

apprenticeship, or by a few months of study. Some of the less obvious examples are stenographers, bookkeepers, telegraphers, locomotive engineers, pilots, musicians, cooks, interpreters, printers, sign-painters, and photographers.

5. Persons in authority, having some executive ability, but not requiring any originality or higher education, and not elected by the people. *E.g.*, foremen, managers, chief clerks, sea-captains, manufacturers, contractors, bankers, capitalists, and proprietors of hotels, large stores, plantations, etc.

6. Professional men and experts, mostly college graduates, who have qualified for their work by a special course of study lasting a year or more; such as lawyers, architects, civil engineers, foresters, chemists, and physicians. Many if not most of these do not work on a salary basis, but get their remuneration irregularly from a large number of clients or patients.

7. Altruistic public servants, who work for several or many people simultaneously, and influence them for good at little or no cost to each individual benefited. To this class belong most if not all educators (perhaps excluding young teachers of limited experience who are not making that their life work), clergymen, missionaries, journalists, lecturers, and philanthropists. In education they rank about equally with those in class 6, but their ideals are usually higher, and their remuneration less in proportion to the value of their services than in any of the preceding classes.

8. Public officials and statesmen, elected by the people, or holding high appointive positions, like judges, ambassadors, commissioners, and cabinet members. Perhaps presidents of colleges, railroads, large corporations, etc., and elected officers of nation-wide organizations, should be included in this class, and officials of small communities, who have some other business that takes up most of their time, excluded.

9. Persons whose chief occupation is adding to the sum of human knowledge, or writing or doing things that have not been said or done before,[4] such as investigators, explorers, inventors, scientists, poets, novelists, humorists, cartoonists, composers, artists, "empire builders," and perhaps even holders of world records in athletics. It is on this small class, constituting (in the United States something like one ten-thousandth of the total population, that the progress of civilization mainly depends.

[4] New ideas, methods or principles should be the test rather than mere new facts, otherwise newspaper correspondents, detectives, crop reporters, census enumerators, tax assessors, surveyors, etc., would have to be put in this class. But almost every one who habitually writes books or magazine articles (other than mere hack-writers) or composes music or poetry or turns out inventions or works of art belongs here.

There will doubtless be some difference of opinion as to the relative rank of some of the occupation classes just outlined, but in a general way those in the higher classes have the most education and the widest spheres of influence, and are fewest in number, as will be shown by some of the curves selected for illustration farther on.[5] As a rule persons in any one of the grades have passed through some or most of the grades below it before attaining their present positions; but this is not a strict linear sequence like the educational grades, for classes 0, 4, 6 and 8 are more often side branches with no outlet than stepping-stones to something higher. Or to put it in another way, many persons reach groups 5, 7 and 9 without passing through those immediately below.

Of course it is impossible to draw sharp lines between the different occupation groups, on account of the endless variety of occupations in our complex civilization,[6] and also because there are at all times large numbers of persons in a state of transition from one group to a higher one. But such difficulties are inherent in almost all classifications, and need not be regarded as insurmountable. (Very similar difficulties are encountered, for example, in defining the zones of vegetation on the slopes of a high mountain; and in the case of a complex mountain system, with a considerable variety of soil and exposure conditions, it may not always be certain which of two non-contiguous zones is the higher.)

To apply the criteria here proposed to the measurement of civilization, let us suppose that each individual in the community and group under consideration (be it total population or only adults, natives, whites, males, or some other restricted group) has been given a decimal rating in education and occupation.[7] The sum or average of the two might be called his civilization number or coefficient. A curve could then be con-

[5] The results of a psychological rating for United States soldiers taken from a number of different occupations in civil life, published in *Science* for March 14, 1919 (page 358), agree pretty well as far as they go with the sequence here adopted. Even the Russian Bolsheviki are reported to have grouped the workers of that country a few months ago into about thirty categories in ascending order, with fixed salaries for each, ranging from 370 rubles per month for apprentices and beginners to 2,200 for certain public officials. Their classification, as published in some of our daily papers, bears some resemblance to the one here proposed (which was worked out in nearly its present form in the summer of 1917, but not published until now). Confucius is said to have divided the workers of China into four grades over two thousand years ago.

[6] The last United States census recognized about 17,000 different occupations for purposes of enumeration, and assembled them in 428 groups in the published returns.

structed having for its ordinates the civilization numbers, and for its abscissas the number or percentage of persons ranking at and above any given number. With a decimal rating in two different lines we would of course have instead of a curve a series of twenty steps of the same height and varying width, but if the number of grades were increased the steps would approach more nearly to a smooth curve, steepest among the higher grades, like a similarly constructed curve for the ages or wealth of the population, cities or farms arranged in order

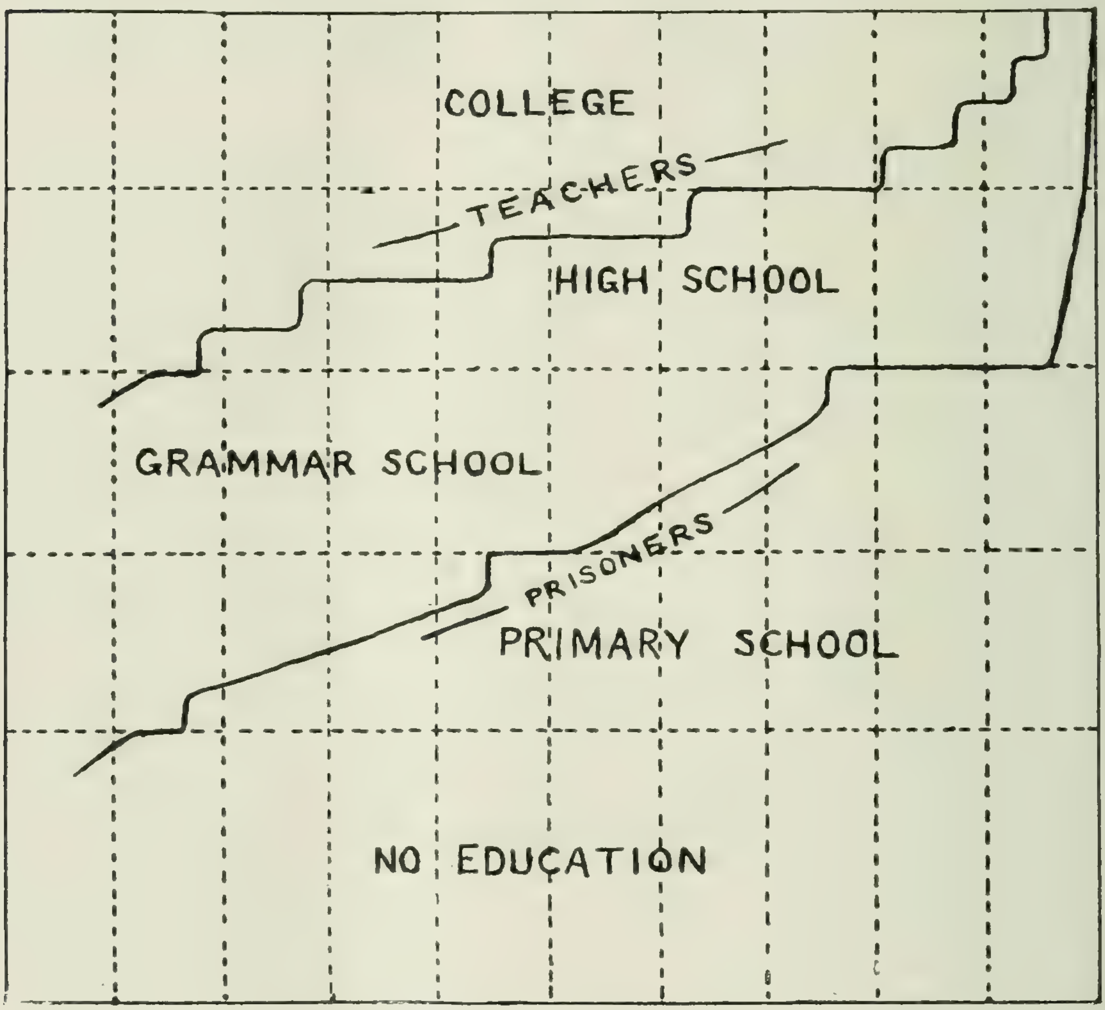

Fig. 1. Education Curves for 3,648 Alabama Teachers and 2,500 Indiana Prisoners, based on 1910 Statistics.

of size, species of trees in a forest in order of abundance, and many other things easily called to mind.

To illustrate the workings of the system two graphs are presented. As there seem to be as yet no available data giving both education and occupation simultaneously for any considerable portion of the population, the two kinds of ratings are treated separately.

[7] If it were possible to add psychological tests to the educational and occupational inquiries here proposed we might have a still more satisfactory measure of civilization.

In both graphs horizontal distances represent percentages, and the vertical lines divide the figures into ten equal parts to facilitate measurement. On any horizontal line the distance from the point where a given curve intersects it to the right-hand edge of the figure represents the percentage of the total number who rank above that point, and *vice versa.* The average rank of any curve is of course proportional to the area between it and the base. Nearly all the persons on which these curves are based are adults; but if the total population of any normal community were graded in this way the large number of children would probably make the uneducated and unemployed classes the largest.

The first graph rates according to education two groups far apart in the social scale, namely, 3,648 rural and village teachers (including both white and colored) in Alabama, and 2,500 inmates of the Indiana State Prison. The figures for teachers are taken from Bulletin 41, 1919 series, of the U. S. Bureau of Education, and those for prisoners are from a newspaper abstract, published last spring, of an article by Dr. Paul E. Bowers of the institution named.[8]

Vertical distances in the education graph represent the amount of schooling, on the assumption that a normal individual who goes through college enters school at the age of six and spends four years in each of the four divisions indicated, graduating at twenty-two. Each curve in this case represents a single occupation group (number 7 in one case and 0 in the other), so that if education and occupation were being rated simultaneously the curves would still be of the same shape, but farther apart.

[8] Very likely some additional data of this kind could be found, but these are all that have come to the writer's notice recently. There are some educational statistics in " Who's Who in America," but they give only two or three points on the educational curve, and about half the persons listed in that work are college graduates, not further classified as to education.

If we could construct an education curve for the whole adult population of the United States it would doubtless lie between the two shown in Fig. 1. As pointed out above, the census gives us only one point on such a curve, namely, the percentage of illiterates. In 1910 the illiteracy percentage for adult males of all races and nativities was 8.4 in the whole United States (24.3 in Alabama and 4.1 in Indiana). The number of college graduates for the whole country—but not for single states—can be estimated approximately from the table of colleges in the New York World Almanac. From that it appears (after making due allowance for omissions) that there are something like a million living college graduates in the United States, which is about 1 per cent. of the total population or 2 per cent. of the adult population. Or if the sexes were separated it would probably be found that about 3 percent. of the men in this country are college graduates.

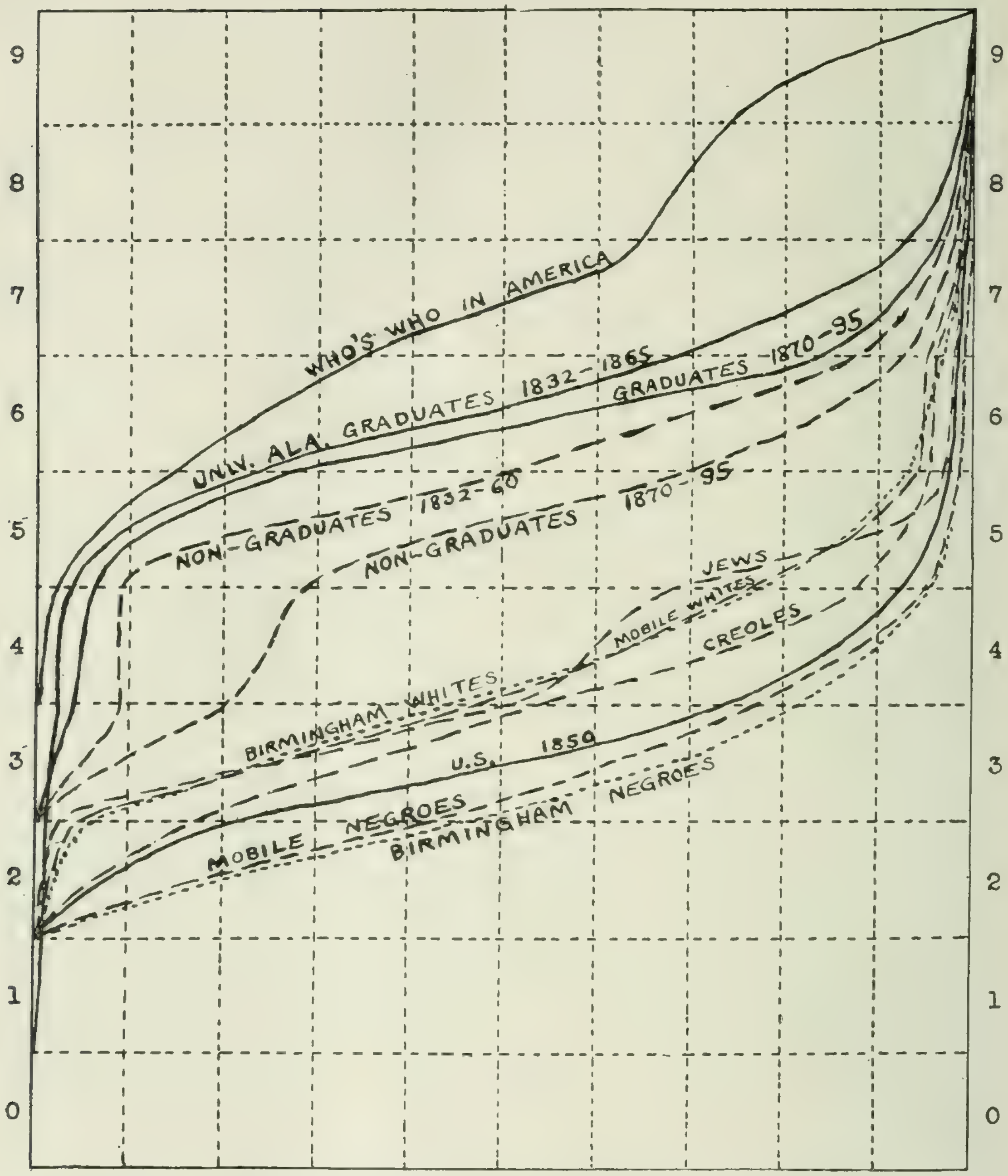

FIG. 2. OCCUPATION CURVES FOR THE FOLLOWING TWELVE GROUPS.

1. First 1,000 names in "Who's Who in America," 1916 edition, excluding a few cases difficult to classify.
2. 373 graduates of the University of Alabama, 1832–1865.
3. 674 graduates of the University of Alabama, 1870–1895.
4. 586 non-graduates of same, 1832–1860.
5. 1005 non-graduates of same, 1870–1895.
6. 959 white persons in Birmingham, Ala., whose names begin with A. (1913.)
7. 527 negroes in Birmingham, Ala., whose names begin with A.
   (The Birmingham curves are dotted lines.)
8. 564 white persons (including Jews and Creoles) in Mobile, Ala., selected from first part of alphabet.
9. 281 supposed Jews in Mobile.
10. 156 Creoles in Mobile.
11. 749 negroes in Mobile, selected from first part of alphabet.
12. 5,307,347 free males over fifteen years old, gainfully employed in the United States, 1850.

The numbers at the sides correspond with the occupational groups defined in the text.

The second graph is based on occupation only, and includes twelve different curves. The vertical distances correspond with the ten occupational grades above outlined, and are numbered accordingly. For the sake of simplicity it is assumed that each step on the occupational ladder is of the same height, there being apparently no rational method of determining how much they should differ, if any.[9] And for the sake of appearances all the curves are drawn as smoothly as possible, on the assumption that no two persons are of exactly the same rank, and that there are all gradations between the highest and the lowest. For any one curve the number of persons in any occupational group is measured by the horizontal distance between the points where it cuts the upper and lower boundaries of the group; so that gentle slopes indicate large numbers and *vice versa.*

The uppermost curve in this graph is based on the first thousand names in the 1916 edition of "Who's Who in America," and probably does not differ noticeably from that which might be derived from the last thousand or any other large number in the same work. It would have been comparatively easy to construct separate curves for men and women, married and single persons, natives and foreigners, persons with German, Jewish, Irish or Scandinavian names, different age groups, residents or natives of different states, or of cities and rural districts, and those with different religious or political affiliations (where such are indicated), but that would have taken considerable time and complicated the graph too much.

The next four curves are based on graduates of the University of Alabama, and matriculates who did not graduate, both living and dead, in two different periods of approximately equal length, before and after the Civil War. The data are taken from an alumni catalogue published in 1901. Those whose occupations were unknown to the compilers of the catalogue, or who died before embarking on their life work, have been left out of the calculations, so that practically none falls in the unemployed class except a few retired business men.

The higher rank in civilization of graduates as compared with non-graduates is just what one would expect, and illustrates graphically the effect of higher education. The higher

[9] It is possible, however, that it would be nearer the truth to make the upper steps wider, for there seems to be greater diversity of ability among the higher classes than among the lower. For example, one unskilled laborer is about as good as another, which can not be said of managers, teachers, or scientists. And it is easy to prove by means of statistics of illiteracy, farm building values, etc., that in those parts of the United States having a large colored population there is more variation among the whites than among the negroes, even where the latter are decidedly in the majority.

rank of the ante-bellum students, both graduates and non-graduates, may be due to more than one cause, but the principal one is doubtless that at the time the record was made, in 1901, many of the students of 1870 to 1895, especially the later ones, had not reached as high a station in life as they did later. This is borne out by the comparatively large number of public officials among the ante-bellum graduates—for one does not usually get elected to public office until middle life—and by the number of post-bellum non-graduates still in the clerk and book-keeper classes in 1901.

The continuous curve below the middle of the graph is for all white and free colored males over fifteen years old in the United States returned by the Seventh Census as having gainful occupations in 1850; they are 5,371,876 in number, from which however have been deducted 64,529 that are hard to classify. That census recognized 325 different occupations, most of them designated by only one or two words, and all arranged in an alphabetical list with the number of workers assigned to each. (Similar data were also given for each state.) With occupations so briefly characterized it is often difficult to determine the proper rating, and it is pretty certain that two or three different grades are sometimes combined under a single word, such as agents, dealers, farmers, jewelers, lumbermen. But the errors of judgment tend to balance each other to a considerable extent when so many are involved, and the resulting curve harmonizes very well with others near it. Similar curves could be constructed for separate states and later censuses, thus affording opportunities for some interesting comparisons.

The remaining six curves are derived from the 1913 directories of Birmingham and Mobile, Alabama, both published by the same company.[10] In order to make these curves comparable

[10] R. L. Polk & Co., of Columbus, Ohio. A city directory usually lists about a third of the total population, mostly adult males. Wives are not mentioned at all in the Mobile directory, but in that for Birmingham their existence is indicated by their first names in parentheses following the husband's names (in the case of the white population; among the negroes the married men are indicated by a special symbol, but the wives' names are not given). In both directories the occupation, if any, of each person listed is given in a word or two (usually abbreviated), and even less explicity than in the 1850 census above mentioned, so that there is room for many errors of judgment; these, however, must neutralize each other to a large extent in the final summation. Persons whose occupations are not given seem to be mostly widows keeping house for their children, and young ladies not employed outside their homes.

The criminal class of course does not figure as such in these directories (or in census enumerations), because some of them have unmentionable occupations, some have no fixed habitation and thus escape enumeration, and some are confined in penal institutions.

with others the unemployed persons are disregarded, for there is no sure way of distinguishing between the busy housekeepers on the one hand and the debutantes, society women and superannuated people on the other.

The Birmingham directory puts all names in a single alphabetical list, designating negroes by a star before the name. The Mobile directory lists the two races separately, and in the list of whites uses a special symbol for the Creoles, who constitute a little more than 1 per cent. of the whites or about 3/4 of 1 per cent. of the total population (but have never been distinguished in census reports). The curves for whites and negroes in both cities as presented here are based on only a few hundred names at the beginning of the alphabet, but the results are probably accurate enough for present purposes.

For Mobile there are given here two additional curves, one for Jews and one for Creoles. The number of Jews in this or any other American directory can not be estimated very accurately, but they were identified as far as possible by their names, all the way through the alphabet.[11] And even if a large number were overlooked in the count that should make no particular difference in the occupation percentages. The count of Creoles aimed at completeness. The whole number of them found in the directory was less than 200, and eliminating those whose occupations were not given left only 156, rather a small number for accurate results, but the curve lies between those for whites and negroes in the same city, as we should expect. The curve for Jews also fulfills expectations in being strong in proprietors and clerks, and weak in skilled and unskilled laborers and public officials.

The contrast between whites and negroes in the proportion of unskilled laborers is very marked, as would be expected. Of course none of the college men or celebrities are in that class at all. One would have hardly expected so much similarity between the curves for the ancient seaport of Mobile and the modern manufacturing city of Birmingham, scarcely forty years old. The fact that the different curves do not cross each other much is rather significant.

A city directory naturally gives no direct information about the educational equipment of individuals, but even if it did and that had been utilized in constructing these curves—as should be done whenever it becomes possible—it probably would not change their shape much, for persons in the higher occupations commonly have the most education, as already stated.

[11] By this means it was estimated that Jews constitute about 2 per cent. of the white population or a little more than 1 per cent. of the total population of Mobile.

It is interesting to note that if the space for class 2 in the occupation graph were bisected by a horizontal line that would cut each curve at a point corresponding approximately to the illiteracy percentage of the group represented thereby;[12] which would harmonize very well with an assumption that half the unskilled laborers but very few of those belonging to the higher classes are illiterate.

Although the occupation data have been compiled rather hurriedly, without any attempt at extreme accuracy, the curves serve very well to illustrate the differences between several diverse population groups in a new way, and to demonstrate the validity of occupation as a test of civilization. If we had such curves for many different countries the knowledge should be extremely valuable for many purposes. For example, it would shed new light on the question of which nations are fitted for a popular government and which should remain monarchies or dependencies for some time to come. For a country or community with not more than half of its adult male population above the rank of unskilled laborers—a condition approximated by the two lowest curves, and probably also by Liberia, Haiti, Mexico, and several other tropical countries—could not be expected to govern itself very well if all the men had an equal voice in public affairs.

Some such point of view would have been useful in this country about two years ago, when large numbers of men were being classified for military service. Many of those shown by psychological tests or otherwise to be too low in intelligence were excused,[13] but little or no allowance was made for the few at the other extreme, men of higher grade than the lawmakers and military authorities (and therefore presumably too valuable for military service), except in the case of those above the age limit and a few special easily defined classes like clergymen and public officials.[14]

At various times in the last century or two, particularly in Russia since 1917, and in this country since the close of the recent world war, groups of men in occupation classes 2 to 4 (who are naturally not well grounded in the fundamentals of economics and sociology) have sought to divert by one means

[12] There are of course no illiterates among the "Who's Who" people and college men, and probably very few among the Jews, in the South at least. The illiteracy percentage for white and free colored persons over twenty in the United States in 1850 was given by that census as 10.35. That for adult males in 1910 in Birmingham was 2.3 for whites and 23.0 for negroes, and in Mobile 1.1 for whites and 25.1 for negroes.

[13] See *Science*, II., 49: 53–61, 221–226, 251–259, 1919.

[14] See B. E. Livingston, *Science*, II., 49: 202, 203, February 28, 1919.

or another to their own use some or all of the share of the profits of industry that rightfully belongs to the small minority of "bourgeoisie" who supply the brains or the capital, on the theory that those who work with their hands should have all the proceeds of their labor, and that mere numbers should dominate irrespective of ability, and regardless of how much inconvenience or injustice to innocent parties results from their selfish demands. Such attempts are rarely completely successful, however, for the obvious reason that civilization without competent leadership (classes 5 and upward) is impossible.[15]

When census methods become sufficiently refined so that civilization can be studied graphically in some such way as that here proposed for a long period of years, it will probably be found that the average rating of any one community, unless it is small enough to be affected materially by immigration and emigration, changes very slowly; although conceivably the shape of its characteristic curve might fluctuate locally or temporarily in response to educational and child-labor legislation or other influences. Although we seem to have made phenomenal progress in some lines in recent decades, it is chiefly in the sum total of human knowledge—that can be stored up and disseminated by means of the printing press, which did not exist a few centuries ago—rather than in individual efficiency.[16]

Some caution should be used in making comparisons by this method between different countries, or even different sections of a large country like ours, for it might not be fair to measure such different types of civilization as American and Japanese, or Yankee and Southern, by the same standards, at least until some more refined system is devised. But persons who have the time and inclination can easily give the plan a further trial with various city directories, alumni catalogues, biographical dictionaries, etc., without waiting for the census to take it up; and very likely many improvements can be suggested.

[15] If it was at all practicable it would be an interesting experiment to turn over to these insatiable toilers (some of whom have long been earning more than brain-workers who have far more education and experience and could make much better use of the money if they had it) for a time a few mines, newspapers, factories, railroads or islands, and see how long they could run them successfully without foremen, proprietors, experts, teachers, editors, lawmakers, inventors, writers, etc. Very likely sooner or later men would arise from the ranks of the laborers to fill these higher positions, but if so conditions would then be essentially the same as before the beginning of the experiment.

[16] In this connection see the abstract in *Current Opinion* (67: 106–107), for August, 1919, of a newspaper article by Dr. Charles Gray Shaw on knowledge as the cause of inefficiency.

FINIS CORONAT OPUS

By FRANK V. MORLEY

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THE evening vigil may be approached in many ways. Perhaps the pleasantest of all is to fortify the soul with plenty of tobacco, a canister of crackers and something potable to fall back upon, and a volume of the inimitable Robert Burton. But failing the "merry companionship" of the younger Democritus, we should be prone to choose the scientific remains of a poor, neglected, and forgotten scholar whose name was also Robert, but who was earlier in his unhappy life at Oxford by some fifty years.

It is scarcely unjust to say "forgotten"; save for a very occasional mention as the first in mathematics to use our present symbol for equality (and that is doubtful tenure upon fame!), who nowadays ever hears of Robert Recorde? Yet in its day "The Whetstone of Witte" was a famous book, the first treatise in English on arithmetic. It is affirmed that with the time of Recorde the English became conspicuous for numerical skill, and that after him the higher branches of mathematics began to be studied. But we can hardly say this was because of Recorde's work. As he prepared his book there was preparing another potent whetstone to activity, the Spanish Armada; his treatise was launched into a rising sea of intellectual interest, and the numerical skill of his contemporaries may have been due to their practise in dead reckoning and the impulses of trade, rather than to the direct influence of Recorde.

The generations which gave us Shakespeare and Spenser did not, however, give us much of scientific worth. Perhaps the interests were as yet too speculative, and the ideas too tenuous to avoid burial in argument. Until a statement is reducible to algebra, there will be no lack of polemics pro and con; and in those days algebra was treated as an empiric rather than an aid to thought. So Recorde, though he had a clear field ahead of him, yet handicapped himself by agreeing with his times.

But even among the scientists of his own day, Recorde stands nowhere as a creative figure. The restless and discursive Cardan, the silent Tartaglia, and the brilliant but lazy young Ferrari, were in an atmosphere far keener in research. Among teachers, many were better than our Oxford scholar. His reach was not great, and his mental footwork far from perfect. As a mathematician and as a medical man, we may let him pass; his contributions are hardly memorable enough for passage through the crowded centuries, save for their personal note. But here they breathe a sweet and a pathetic fragrance. His quaint and now archaic dialogues, the nice imaginary courtesies between the Master and the Scholar, his appeals to all those that love "honeste learnyngo," and above all, his sorry ending, make his a worthy case to ponder in the midnight hours.

There are various ways in which men have been done to death in their following of intellectual pursuits. There is a considerable band who suffered from an overdose of study, conspicuous with their young leader, Henry Kirke White. It was Henry, we remember, who was kept after school as a boy and consequently wrote

> How gladly would my soul forego
> All that arithmeticians know, . . .

When he went to Cambridge he was ranked as the best man of his year, in spite of the condition of his health, and mathematics was his only weakness. In mistaken kindness his tutors decided to keep him at work all summer on mathematics, instead of granting him the holiday which his epileptic case bespoke. And in July, while at work on logarithm tables, he was overtaken by a sudden fainting fit, with death following shortly after. Was anybody prosecuted for the flagrant case of homicide?

It was not overstudy which made an end of Robert Recorde in 1558, but rather what he calls the "sodaine unquietnesse" of the time. There is something appealing in the abrupt ending of his book. An abstruse discussion of universal roots is suddenly thus interrupted.

Master. You saie truth. But harke, what meaneth that hastie knockyng at the doore?

Scholar. It is a messenger.

Master. What is the message? Tel me in mine eare.

Yea, sir, is that the matter? Then is there no remedie, but that I must neglect all studies and teaching, for to withstande these daungers? My fortune is not so good, to have quiete tyme to teache.

Scholar. But my fortune and my fellowes is much worse, that your unquietnes so hindreth our knowledge. I praie God amende it.

Master. I am inforced to make an eande of this mater: But yet will I promise you, that whiche you shall chalenge of me, when you see me at better laiser: That I will teache you the whole arte of universall rootes. And the extraction of rootes in all square surdes: with the demonstration of theim, and all the former woorkes.

If I might have been quietly permitted to reste but a little while longer, I had determined not to have ceased till I had ended all these thinges at large. But now, farewell. And applie your studie diligently in this that you have learned. And if I maie gette any quietnesse reasonable, I will not forget to performe my promise with an augmentation.

Scholar. My harte is so oppressed with pensivenes, by this sodaine unquietnesse, that I can not express my grief. But I will praie, with all theim that love honeste knowledge, that God of his mercie will sone ende your troubles and graunte you suche reste as your travell doth merite. And all that love learnyng say thereto, Amen.

Master. Amen, and amen.

These were the last words he printed. The message was a simple one, and familiar to teachers in all ages. It was a summons to the Fleet for debt. In days of pestilence and plague, this was equivalent to sentence to death by slow torture. Within the year disease had played its part, and he died among the miserable surroundings.

Poor Robert! He never got the "quietnesse reasonable" or the "better laiser" for performing his promise "with an augmentation." Nor did the charming affection shown by his scholar ever bear the fruits of future pupils. "God of his mercie" ended his troubles soon enough in death, but his gentle moan lives through the years as evidence of the passing of a kindly spirit, not a great one.

Half a century later, it is recorded in the Will of the other Robert that we spoke of, Robert Burton, that he gave a hundred pounds to his nephew, "nowe Prisoner in London, to redeeme him." Robert Recorde had no kindly uncle to play Democritus, and help him out. Well indeed might he have cried, *O viveret Democritus.*

Or, for that matter, well might we, nowadays.

ON RHYTHM.

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A PHENOMENON which may be called rhythmic is one that recurs at equal intervals of time or at any rate not at cognizably unequal ones. The dripping of water from a leaky tap is rhythmic, but the murmur of the brook is not. The universe is full of rhythms. The succession of the seasons, the alternation of day and night, the phases of the moon, the ebb and flow of the tide, the recurrence of spring and neap tides, the November flight of meteors, the yearly rise of the Nile, and so forth, are all examples of cosmic rhythms. The magnitude of the time interval or period of the rhythm is not of the essence of rhythmicality. Thus, the behavior of the ether in transmitting light waves is rhythmic, the frequency being only some billionths of a second; whereas the return of a comet such as Halley's to our solar system, although a matter of seventy years or so, is just as rhythmical; its reappearance is periodic.

Music is essentially rhythmic; in fact, it is the periodic character of the vibrations of the air that constitutes music as opposed to noise. The vibrations of the air objectively constituting noise are highly irregular or arhythmic.

A clap of thunder is not rhythmical. In a rhythm something recurs at equal intervals of time; if this something recurs at unequal intervals, the rhythm sometimes is spoken of as irregular. This usage would make the word "rhythm" synonymous with regular rhythm, which is the general acceptation and the one in which the term will be used in what follows. It is owing to the regularity of recurrence of eclipses, the equinox, meteors, comets, etc., that these phenomena can be predicted with an accuracy that makes astronomy as an exact science so justly admired. The periodicities of rhythms in the non-living world may be matters of years, months, weeks, days, hours, minutes, seconds or fractions of a second.

Coming now to the realm of Life, we find rhythms pervading everything. The plants, with striking regularity, have their own times each year for putting forth the buds, unfolding the leaves, bursting into flower and finally allowing all the perfumed beauty of the flower to fade in order that the fruit shall be formed as a life in death. Thus the poetess sang,

> "Leaves have their times to fall,
> And flowers to wither at the north wind's breath;
> Thou hast all seasons for thine own, O Death!"

In plain prose, there is no rhythm about Death.

"Chestnut Sunday" is approximately the same Sunday, and "Apple Blossom" week is practically the same week each year. The opening and closing of flowers is rhythmic, the rhythm depending on the waxing and waning of the intensity of daylight.

Doubtless the most familiar rhythms are in the world of animal life. Here we have rhythmic actions of animals as in flocks and herds, of animals as individuals, and of the organs, tissues and cells of the animal body. The migration of birds is annual in rhythm. It is only part of the truth to tell us that the waning light and diminished heat and food are what constrain the birds to leave us: they know *when* to leave us. Migratory birds which have spent all their lives well-fed in the captivity of Regent's Park, nevertheless become restless at the approach of autumn. Again, those animals which hibernate during the winter know when to betake themselves to their hiding-places, whence they come not forth until the spring.

The rhythm of the sexual activities of birds is one of the most characteristic things about their behavior. It is only in the spring that the "lovelier iris gleams upon the burnished dove," but it is *every* spring. Even a brainless (decerebrated) pigeon will "coo" energetically at the breeding season, although if the hen bird be placed near him he will take no notice of her. The sexual rhythm is inherent in the lower parts of the nervous system, but in the absence of the brain it is a meaningless and mechanical rhythm.

Practically all the activities of one's daily life are rhythmic; the most obvious perhaps being the regular alternation of waking and sleeping. There is a well-marked rhythm in our digestive organs, in the organs of excretion, and most pronouncedly in the beating heart.

Rhythm pervades the world of animal life: just watch that transparent jellyfish in the limpid summer sea, and you will notice how the edges of the umbrella contract or pulsate with slow and regular rhythm (about 30 in the minute). Equally obvious rhythms are those of the wings of birds and other flying things; of the legs in walking and dancing; of fins in swimming. Large birds fly with slow, leisurely rhythm, small birds with a fast one; just as tall men have a slow stride, short men a more rapid step. Regular rhythms are everywhere; if Nature abhors a vacuum, she also abhors fits and starts: living Nature does everything "decently and in order."

The periodicity of the heart's action is an excellent example of a rhythm of animal origin. Seventy-two times in the minute this wonderful hollow muscle contracts (systole) on the contained blood forcing it out into all the arteries of the body, and seventy-two times in the minute does it dilate (diastole) and suck blood in from the veins leading to it. The duration of its cycle is therefore eight-tenths of a second (60 72), and in health during the many years of a long life it practically does not vary from this value. If, for more than a few minutes, the heart's rhythm remains distinctly irregular, then we conclude that something is amiss with this wonderful organ within our breast.

Sometimes we come across a heart with a congenitally fast rhythm, a condition called tachycardia, and sometimes one with an abnormally slow rhythm, a condition called bradycardia. Whereas the rhythm of the heart-beat is for each individual a certain average rate, it varies in different individuals according to height and age. Thus, tall persons have slower hearts than short people; and infants have a heart rate about twice as fast as adults. The whale and the elephant have very much slower heart-beats than the mouse or the sparrow. The heart-beat in these small animals is so fast that the pulse can not be counted in the usual way: until recently we had no reliable information about it, but by an electrical method used by a physiologist, Miss Buchanan, D.Sc., working in Oxford, it has been ascertained with great accuracy.

The pulse-rate, which is the same thing as the heart-rate, is very much slower in the cold-blooded than in the warm-blooded animals. Thus, in a fish or frog the heart contracts only about forty times in the minute, or about half the mammalian rate. This relatively slow rate can be quickened by making the heart beat in warm salt water, when the rate can be made to exceed that of the normal mammalian heart. A further study of the warm-blooded heart proves to be full of interest. It can be accelerated by warmth and slowed by cold; but it is its affectability by nerve impulses which is so remarkable. It is a matter of common knowledge that the heart can be made to beat much faster at one time and slower at another through nerve impulses alone. Everybody knows that emotions can influence the heart very markedly. Thus, of course, it has come about that "the heart" and certain emotions are taken as synonymous. Certain emotions "disturb it" in that some cause it to beat more rapidly, and some slow it and enfeeble it.

Now physiologists have discovered two distinct sets of nerves which influence the heart-rate; the one set on being stimulated makes the heart faster and stronger (accelerator and augmentor nerves), the other set on being stimulated makes the heart beat more slowly or may stop it altogether (inhibitory nerves). Evidently the former set arouses the heart to greater activity, the latter set induces in it less activity than normal.

The rhythmicality of the heart is not conferred on it by the action of nerves or by the presence of blood or the temperature of the blood, or by any other "external" condition: its rhythmicality is inherent in it, is spontaneous (autogenic). The rhythm of the heart is of the essence of its life: the microscopic cells of the embryo heart beat with a rhythm as soon as they are perceptible at all, and long before nerves have reached them or any blood has been formed.

Spontaneous rhythmicality is the great mystery of life, the central puzzle in biology: if we knew what rhythm really was, understood it "all in all," we should "know what God and man is." The heart is not the only rhythmic portion of the circulatory system. In all animals, portions of the large veins have the power of rhythmic contraction—in the bat sixteen times per minute—and in some animals (frogs, for instance) there are pulsatile sacs or lymph-hearts, dilatations of the lymphatic vessels beating visibly under the skin of the back.

Many other organs exhibit rhythms. The activity of the stomach is rhythmic, also that of the intestines; over which waves of contraction pass at short intervals, the activities also of the gall-bladder, the urinary bladder, and the uterus are all rhythmic.

An interesting thing about rhythmic organs is their inability to have the rate of their rhythm forced beyond a certain limit. No amount of stimulation of the accelerator nerves can increase the rate of the heart-beat beyond a certain limit. Similarly, heating the heart will raise the rate of the rhythm, but only up to a particular figure which can not be exceeded. Working with the pigeon, the author found that the greatest number of beats per minute which the heart (auricle) could give was 300, or five a second; and beyond that it was not possible to force it. Not only, then, is rhythmicality inherent in the living substance of the heart (cardiomyoplasm), but also a power of resisting all influences to accelerate it beyond a certain limit, a kind of "functional inertia," as the author has called it.

Let us now take another example of rhythmic activity as seen in the cilium. A cilium is a minute, whip-like process of living protoplasm projecting from the surface of the cell. There are millions of these cilia covering the mucous membrane of nose, throat and bronchial tubes, where they are for the purpose of lashing mucus, dust and germs towards the nostrils and mouth, respectively. Now, these cilia lash backwards and forwards at a characteristic rate of ten to twelve times in the second. Just as the heart makes 72 systoles and 72 diastoles in a minute, so the cilium bends forwards ten times and backwards ten times in a second, or six hundred times a minute, about eight times as fast as the heart. Otherwise put, the period of ciliary oscillation is one tenth of a second instead of eight tenths.

But the rhythmicality of the cilium is as inherent as that of the heart. The cilia receive no nerves, therefore not being innervated they can not possess any rhythm conferred on them from outside by nerves (neurogenic). The cilia are, however, easily influenced in their rate of vibration by changes of temperature and by drugs and poisons. By warming the cilia they lash faster and faster until they attain a speed of about twenty a second, beyond which they can not go; one more example of a limit set. Conversely, cold and narcotics like chloroform slow and finally stop the action just as they do in the case of the heart.

Let us now enquire into the rhythms exhibited by muscles and nerves; almost everybody knows that muscles act (contract or shorten) by having nerve-impulses sent into them either by the will or in an involuntary manner. Soldiers who were wounded in the late war soon came to be aware that if one of their great nerves was cut, they had no longer any power to move certain muscles which they learned to call "paralyzed." Now, these nerves all come from the central nervous system, so that the impulses they transmit must also have their origin in that system. The nerve cells which give rise to these nerves and nerve-impulses are called nerve-centers, and it is these centers which emit impulses to the muscles in a definite rhythm.

Let us take the case of breathing. Normally, an adult breathes about sixteen to eighteen times a minute, that is to say, in a wholly unconscious fashion his diaphragm—the great, curved muscle between the chest and the abdomen—descends eighteen times and rises eighteen times in the minute. There is, therefore, a respiratory rhythm just as there is a cardiac and a ciliary. Now, the diaphragm would not make any descents were it not that it was receiving nerve-impulses through its nerves (phrenics). After these nerves have been cut, the diaphragm is absolutely still. Clearly, then, the rhythm of the activity of the diaphragm is not inherent, but, on the contrary, is conferred by nerves or is neurogenic. The rhythm of 18 to 20 a second must be the rhythm of discharge of nerve impulses from the nerve cells or centers from which the phrenic nerves come. It is the nerve cells that have this rhythm, not the nerves as conductors and not the diaphragm as a muscle.

The actual cells from which the phrenic nerves proceed are, however, not the breathing center, which, situated further up in the central nervous system, constrains the phrenic centers to issue their periodic discharges of nerve-impulses. It is the chief respiratory center, therefore, that has the real respiratory rhythm, which, like the heart's, varies with age and other circumstances. We know very well that the rate of breathing can be profoundly altered by emotional states; some conditions, states of excitement, greatly increase the rate, others slow it or stop it for a time, as in the phrase, "it fairly took my breath away."

Experiments have shown that heated blood accelerates the breathing and cold slows it, and there are drugs which have analogous actions. Further, the will can, for a time, abolish the rhythm altogether. Divers are able intentionally to "hold their breath"; on the other hand the will, if we so wish it, can hurry up the rhythm beyond the rate of the normal. This faculty of having a rhythm which can be altered by the will is quite a rare one amongst the centers of the nervous system.

The normal respiratory rhythm is, then, an additional example of a rhythm inherent in something—in this case in the cells of a nerve center—but capable of responding to outside influences. And again, there are limits set, for neither by the will, nor by emotion, nor by heated blood, nor by drugs, can the rate of the breathing center be forced beyond a certain maximum value.

Breathing is to all intents and purposes an involuntary, unconscious activity: the diaphragm rises and falls throughout life whether we wake or whether we sleep with a regularity that is as constant and with efforts that are as untiring as those of the heart itself. In a word, the rhythm of breathing is not voluntary, although we can interfere with it voluntarily.

But, of course, the nervous system can give us plenty of examples of rhythms of voluntary origin. Take the very simple case of tapping one's finger on the table or on an electric key. I can tap my forefinger once a second, twice a second, three times a second, and so on, until I am tapping it so fast I can barely count it. When this rate is reached, an instrument of simple construction can prove that the finger is being flexed and extended at about ten to twelve times a second. We may note in passing that this is exactly the same as the ciliary rate. Now the instrument will show that beyond ten to twelve a second the ordinary person can not go, although it is possible to train musical technicians to "trill" at a considerably greater rate than that of ordinary people. Still even for experts a limit is soon reached. The rhythm of the cells of the centers giving rise to the nerves to the fingers is evidently of this sort that whereas the cells can be made by the will to assume any slow rhythm from one to twelve a second, they can not be forced beyond that limit.

What, then, is the rate of inherent rhythm of these centers? Probably ten to twelve a second; although all physiologists are not agreed on this figure, and the point is one not suitable for discussion in the present essay. It is reasonable to suppose that these cells have a normal, natural, inherent rate of discharge which may be one and the same as their maximal rate. Neither by the will nor by artificial stimulation can this maximum be exceeded, not even when the rhythm of the artificial stimulation is much higher than twelve a second. The nerve cells have physiological inertia towards rates of stimulation greater than that of their own maximal rhythm. The respiratory center, on the contrary, we saw, had a normal rate which was *not* also its maximal.

Rhythm or intermittency pervades the nervous system. It has been ascertained that we can not utter syllables (articulate) at a greater rate than ten to twelve a second. What we may call the articulation center has its upper limit set at that figure which we have so frequently met with. The numerical identity of the rhythms of cilium, musculomotor nerve-center, and articulation center can not be accidental.

The periodicities of insects' muscles are of the following orders: The wings of the dragon-fly vibrate at 28 a second, those of the wasp at 110, of the bee at 190, and of the house-fly at 330 per second. The late Professor Mosso asserted that the pitch of the note of a bee setting out on its day's rounds was perceptibly higher than that of the note heard at the close of the day.

It is probable that the receiving or sensory portions of the brain are constructed in such a manner that they, too, have limits in dealing with rhythmic or intermittent presentations.

The spokes of a slowly rotating bicycle wheel can be perceived as separate bright lines, but when the wheel is revolving rapidly the individual spokes fuse into one bright metallic surface, just as the separate slats of a paling viewed from an express train fuse into one continuous surface. The grooves of the milling on the edge of a metal disk spun rapidly under the finger are perceived as constituting a rough but continuous surface. The fusion of the members of a series of instantaneous photographs of moving objects presented in very rapid succession to the eye, as in the kinematograph, is due to this incapacity of the brain to resolve as distinct in consciousness the separate components of the physical series. If the interval between the successive impressions is longer than about 1/40th–1/50th of a second we do not get fusion, but the well-known and disagreeable state of "flicker." These and many other cases prove that there are strict limits to the perception of rhythms by our brains.

The causes of vital rhythms and periodicities are virtually unknown. Physiologists can describe vital rhythmic actions in their own precise language, but that is all. To say that the cardiac cycle is constituted by the two alternating and opposite phases of katabolic systole and anabolic diastole does not bring us any nearer an understanding of the cardiac rhythm. Protoplasm in general tends to act intermittently. Just as a single tap given to a jelly or to a spring will make these oscillate or vibrate for some considerable time thereafter, so a single or continued stimulus given to living matter will cause it to discharge energy in a vibratory or oscillatory manner.

Nor do we comprehend any better the significance of the particular time-duration of the interval between the recurring events which are being studied. Why, for instance, should the heart beat 72 times a minute and not 7 or 700? Why should we breathe 18 times and not 8 or 80 times a minute? Why should the cilium bend 10 times a second as its normal rate and just twice as fast, but no more than that, when urged to do its utmost? These things are mysteries. The rhythms of functional activity in the female reproductive organs are familiar facts of physiology, but what induces the rhythm and why the periodicity should be as it is are problems at present entirely unsolved.

Probably the necessity of rest to prevent fatigue or exhaustion is one of the purposes of vital rhythms. The heart, for instance, can continue to beat so indefatigably just because the duration of its time of rest (diastole) in the cycle is longer than that of its activity (systole). We sleep by night in order to be active by day. All work and no rest is a physiological outrage: rhythm is an expression of that physiological normality in which work alternating with rest is most economically performed.

It is the most familiar things in life that stand most in need of explanation. Rhythmic action is very familiar, but great is the mystery of rhythmicality. That the heart should exhibit its livingness by phasic activity, that the periodicity of these phases should be controlled by nerves and influenced by certain environmental conditions, are the very A, B, C of physiology, but they are also the alpha and the omega of physiological problems.

THE PROGRESS OF SCIENCE

THE CRITICAL SITUATION OF EDUCATION AND SCIENCE

THE present year is a critical point in the development of science. The present fluid state of research may congeal into static frigidity or it may develop energy to transform the world. The events of the last years—to draw on biological as well as physical science for a metaphor—may have resulted in leaving as their offspring infertile hybrids or in a cross-fertilization leading to unexampled productivity. To complete the circle of the sciences, it may be urged that the result depends primarily not on the existing environment or in the inherited organisms, but on the reactions of the latter to the former, and thus on conditions which are to a certain extent under our own control.

The continental nations of Europe must for a generation devote their energies largely to the repair of destruction, and this holds to a certain extent for England. We have suffered serious losses of men and of wealth, but have only drawn upon an available surplus. We are thus free, as most other nations are not, to control our future. Some two billion dollars a year, for example, will accrue from enforced savings through the suppression of the sale of alcohol. This money can be consumed on luxuries for the rich, it can add three per cent. to the comforts of the great mass of the people or it can be used for investments, the most productive of which are education and scientific research.

There has probably never been a period or a nation in which education and science were more highly regarded than at the present time in the United States. It is generally understood that the aggression of Germany in the war was so formidable on account of the development of its industrial civilization based on the applications of science and the thorough training of the people. Russia was helpless before such an enemy; England and France could reply with somewhat similar weapons, but it required the United States to turn the balance. Equally in time of peace, national prosperity depends on science and education. An autocracy, such as formerly existed in Germany, may realize this fact more promptly and apply its knowledge more effectively in practise than a democracy which leaves higher education and scientific research to private initiative or unorganized public support. It is our business to see that the conditions become equally favorable in our social and political system.

At a time when it is important for us to assume leadership in education and research and the people of the country realize the fact, it is most unfortunate that what may be regarded as an economic accident, has intervened to cause serious difficulty. The depreciation in the purchasing power of money is working serious injustice to many individuals, but in no other case has it done such harm to society as in reducing to nearly half the salaries paid to teachers and to scientific men. They may submit to suffer as a part of the cost of war, but the injury to the nation must be remedied. It is consequently a satisfaction to note that action has recently been taken by the scientific and professional men in the service of the government and by the National Education Association to make known the situation. We give extracts from the reports of the two groups.

THE CONDITIONS IN THE GOVERNMENT SERVICE

The committee representing the scientific, technical and professional services report that existing conditions in the federal government service disclose the fact that adequate standards of personnel and of performance are not being maintained, that the situation is becoming worse instead of better, that a force which was depleted by the demands of war has become still further depleted since the cessation of hostilities and that this depletion is proceeding at a constantly increasing rate, until it is only a matter of months before it will be humanly impossible for the experienced personnel remaining to perform adequately the duties devolving upon them. While a certain percentage of turnover in an organization is not harmful and may even be desirable, an annual turnover of 25, 50 or even 100 per cent. and more which is occurring at the present time in the federal government service is disruptive of the organizations, reduces the efficiency of the work and largely increases its cost. It is sufficient here merely to cite examples.

Since July 1, 1918, the Forest Service has lost over 700 employees, or 28 per cent. of its total force, including 460 of its technical personnel. The Coast and Geodetic Survey in the same period lost 33 per cent. of its technical force. The Bureau of Standards lost 16.3 per cent. of its permanent staff in the District of Columbia in 1915–16, 27 per cent. in 1916–17, 48.6 per cent. in 1917–18, and 50.1 per cent. in 1918–19, a total of 840 resignations in four years out of an average force of 535. The separations from the combined technical staffs in Washington and Pittsburgh aggregated 1,400 in the four years, out of an average personnel of 473, making an average annual turnover of 85 per cent. with a maximum in the fiscal year 1918–19 of 145 per cent.

These services require men of specialized training and years of experience in the work to be performed before they reach their full efficiency. It is self-evident that the technical work of the government can not be efficiently or economically performed under such circumstances. It would not be done even if the replacements were by individuals of equal ability, but it is not possible to maintain previous standards in such replacements. Individuals of equal ability will not accept the positions offered, and there must be in consequence a constant reduction of standards in order to fill the vacancies. Not only does the excessive turnover result in reduced amount of work for the same number of employees, and in reduced quality, but it also results in increased cost per unit of work performed. Studies made by the Coast and Geodetic Survey, in relation to its commissioned personnel, show that the aggregate cost during the fiscal year ending July 1, 1920, of using experienced men for training new employees, of lost time due to personnel changes, and of lessened efficiency due to inexperience is likely to be more than 25 per cent. in excess of the total annual payroll for such personnel.

The most serious aspect of the situation is in the fact that the demand from the outside is for the highest grade men, for the trained professional workers and for the best of the administrative officers—individuals difficult to replace in any circumstances, and particularly difficult to replace under present conditions. Many of the most efficient and most valuable employees are leaving; the less efficient and less valuable remain. The net result is a constant deterioration in personnel which, if continued, will eventually result in reducing the government service to a mere training school for private business.

THE SALARIES OF EXPERTS IN THE FEDERAL SERVICE

The committee has segregated 4,332 positions into the various ranks, showing for each rank the number of positions, the mean of the salaries paid in 1919 and 1915, and the percentage of increases in the mean from 1915 to 1919. A temporary bonus of $240 per annum for salaries of $2,500 and under is now in effect. This bonus is applicable to practically all positions in the three lowest ranks, to probably about 75 per cent. of the positions in the fourth rank, to about 10 per cent. of those in the third rank and to none in the second and first ranks. If bonuses are added on these assumptions to the present average base salaries, the total percentage increases in the several ranks since 1915 would be approximately as follows:

TABLE II

Rank	Title	No.	Salary	Increase
1	Senior	51	$5,170	3.3%
2	Full	184	3,275	5.0
3	Associate	408	2,724	8.9
4	Assistant	1037	2,296	17.2
5	Junior	1368	1,872	26.2
6	Aid	1050	1,488	32.2
7	Junior Aid	234	1,152	45.7

The committee states that even if it could be assumed that 1915 salaries were sufficient for maintaining an adequate personnel, it is apparent that the increases since that date have lamentably failed to keep pace with the reducing value of the dollar in which they are paid. Salaries paid in the lower ranks in 1915 were approximately equal to salaries paid for similar positions in private employment. The disparity between government salaries and those paid in private business increased, however, for each step up in the rank of positions occupied. Amounts paid in the full professional, associate and senior ranks were far below the amounts paid for similar employment and responsibilities in private business, with the result that even in 1915 it was difficult to secure and retain an adequate personnel for the higher positions. Nevertheless, in such adjustments as have been made since 1915, these three upper ranks have been practically ignored. It is not surprising that under such circumstances so large a proportion of men in these grades are leaving the government service.

If the flood of resignations from government service is to be stopped and if the service is to be maintained on a standard commensurate with the importance of the work to be performed, there must be a radical readjustment in the present salary scale for the technical, scientific and professional services—a readjustment which will recognize the commercial value of the service performed and realize the fatal blunder of attempting to do the business of the government on a compensation basis which private business abandoned years ago.

After investigation, the advisory committees of the technical, scientific and professional services submit a scale as representing, in their judgment, the lowest amounts under which it will be practicable to recruit and retain in the government service a properly qualified personnel in any class of its technical, professional or scientific work. In support of this scale comparisons are made with rates of pay of skilled and unskilled labor, and certain technical positions under the "Macy Scale," and the salaries received by several hundred government employees who have left the service.

TEACHING POSITIONS IN THE UNITED STATES

THE secretary of the National Education Association reports that more than 100,000 teaching positions in the public schools of the United States are either vacant or filled by teachers below standard, and the attendance at normal schools and teacher-training schools has decreased 20 per cent. in the last three years.

Letters were sent out by the association in September to every county and district superintendent in the United States asking for certain definite information. Signed statements were sent in by more than 1,700 superintendents, from every state, representing 238,173 teaching positions. These report an actual shortage of 14,681 teachers, or slightly more than 6 per cent. of the teaching positions represented, and 23,006 teachers below standard who have been accepted to fill vacancies, or slightly less than 10 per cent. It is estimated that there are 650,000 teaching positions in the public schools of the United States, and if these figures hold good for the entire country there are 39,000 vacancies and 65,000 teachers below standard.

These same superintendents report that 52,798 teachers dropped out during the past year, a loss of over 22 per cent. On this basis the total number for the entire country would be 143,000. The reports show that the shortage of teachers and the number of teachers below standard are greatest in the rural districts where salaries are lowest and teaching conditions least attractive.

The states in which salaries and standards are highest have the most nearly adequate supply of teachers. California shows a combined shortage and below standard of 3½ per cent.; Massachusetts shows 4½ per cent., and Illinois 7 per cent. In at least six of the southern states more than one third of their schools are reported either without teachers or being taught by teachers below their standards. Nearly all of the superintendents declare that teachers' salaries have not increased in proportion to the increased cost of living, nor as salaries have increased in other vocations, and that teachers are continuing to leave the profession for other work.

Reports received by the National Education Association from normal school presidents show that the attendance in these teacher-training institutions has fallen off alarmingly. The total attendance in 78 normal schools and teacher-training schools located in 35 different states for the year 1916, was 33,051. In 1919 the attendance in these same schools had fallen to 26,134. The total number of graduates in these schools in 1916 was 10,295, and in 1919, 8,274. The total number in the graduating classes of 1920 in these 78 schools is 7,119. These figures show a decrease of over 30 per cent. in four years in the finished product of these schools.

SCIENTIFIC ITEMS

WE record with regret the death of Dr. Elmer Ernest Southard, professor of neuropathology in Harvard university; of Dr. Christian R. Holmes, dean of the college of medicine, University of Cincinnati; of Rear Admiral John Elliott Pillsbury, U. S. N., retired, president of the National Geographical Society.

DR. BURTON E. LIVINGSTON has been elected permanent secretary of the American Association for the Advancement of Science, to succeed Dr. L. O. Howard, elected president of the association. Dr. Livingston will retain the professorship of plant physiology at the Johns Hopkins University, and the office of the association will remain at the Smithsonian Institution.

THE SCIENTIFIC MONTHLY

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THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN[1]

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PART TWO

Geological History of Man

HAVING considered the biological position of man and the possibility of his ancestry leading out of the evolution of presumably inferior, and certainly older primate groups, we are in a favorable position for discussion of the earliest evidences of man himself; but before entering upon consideration of the specific problem of human history, it is well to bring to mind certain of the most fundamental conclusions obtained in an inspection of the wide field of history of other living creatures. To one who reads this story, the evidence of the geologic and paleontologic series amounts to a demonstration that our available records of life in the broadest view count up to many tens of millions of years at the least, and possibly reach to hundreds of millions. We see also that in this period the record shows life to have been in an almost continuous state of change; that the life of each period exhibits closer resemblance to that of the periods immediately preceding and following than to the more remote divisions of time; and that series of forms with certain common characters but differing in grade of specialization generally tend toward greater specialization from earlier to later time. The manner in which the modifications take place may not always be understood, and the paleontologist may admit his ignorance of the causes, but the evidence of continu-

[1] Delivered before the National Academy of Sciences in April, 1918, as the sixth series of lectures on the William Ellery Hale Foundation.

ing change and advancing specialization in series of presumably connected or related types seems reasonably clear.

Well within the generally accepted record of the geologist, and forming a part of the life succession of the paleontologist, there appears the human element, taking its place in the life sequence and raising, whether we desire it or not, the question of man's inclusion in the general scheme of evolution, or if his relation to the other biological series, for which we have traced a long history and through which we seem to see running the thread of continuity.

From what we have seen in our paleontologic record there is every reason to believe that there was a long period in which generalized members of the mammalian group were widely distributed and man had not yet appeared. Unless we take the view that man is the product of special creation, built upon lines similar to those of other organisms, we naturally assume that his origin is found in the earlier less specialized type, and by way of an evolutionary process not unlike those that have determined the development of other mammalian forms by modification of types already existing.

The Earliest Remains Referred to the Human Type

Discovery of Pithecanthropus

For the present we shall consider only those relics of man which furnish the earliest known record of the existence of our race upon the earth, leaving for a later paper an account of the succeeding stages represented by the cave men and their immediate predecessors.

Probably no paleontologic contribution published has furnished the basis for more extended and more critical discussion than the paper of Eugene Dubois published in 1894, describing a remarkable tooth, a skull-cap and a thigh bone, found in deposits of considerable geologic antiquity on the island of Java. These specimens presumed to represent a single type, and probably one individual, were first referred to by Dubois in 1892 as *Anthropopithecus erectus* or the erect man ape, assumed to represent a transition between man and the apes. After having with most commendable patience investigated his material for three years, Dubois published his now classic memoir. In this paper the specimens were referred to as *Pithecanthropus*, or ape man, this generic name having been used by Haeckel in 1868 for a hypothetical creature assumed to walk erect, and to have higher mental development than the anthropoids, although not yet attaining to the formulation of speech.

FIG. 1. Locality at which *Pithecanthropus* Remains were discovered on the Bengawan River in Java. After L. Selenka and M. Blanckenhorn.

Following this work of Dubois, extensive excavations initiated by Frau Selenka were carried on in 1907 and 1908 on the site of the occurrence of the type specimen. These important studies added much to our knowledge of the formation in which the Dubois specimen was found, and of the fauna associated with it, but did not contribute additional *Pithecanthropus* remains.

OCCURRENCE AND ASSOCIATED FAUNA

The specimens referred to *Pithecanthropus* all exhibited approximately the same mode of preservation, which is similar to that of the extinct types of mammals found in the same strata, and which have clearly been buried in process of accumulation of the formation. There was no evidence indicating intrusion or burial of these remains in the formation since accumulation, and the relation of the Dubois specimen to the stage of geologic time represented by the deposits containing the mammalian fauna is not seriously questioned.

Some doubt has been expressed, however, whether the skull-cap, the femur, and the teeth belong to the same individual. The first tooth and the skull-cap were found in 1891 only about three feet apart. The femur, discovered the following year, was situated nearly fifty feet from the location of the skull. Inasmuch as the femur is by some considered quite human in aspect, while the skull-cap is assumed to be pre-human, question has naturally been raised as to the relation of these elements to each other. On the other hand, the fact that skull, teeth and thigh bone occurred approximately together, with similar mode of preservation, and with peculiar characters differing from those of all known anthropoids and humans, is considered by many as evidence distinctly favoring the view of Dubois that the specimens all represent one species and one individual. It will evidently not be possible to settle this question with full satisfaction until further occurrences of remains of this most interesting type are discovered.

The *Pithecanthropus* specimens were found in a formation composed in large part of volcanic tuff. It was considered by Dubois as a river accumulation and was assumed by him to

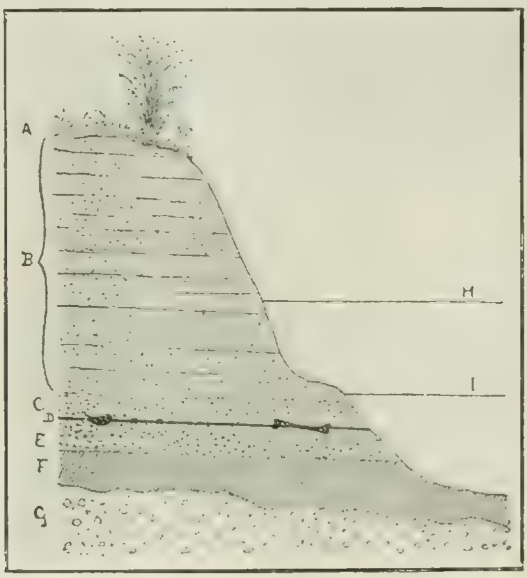

FIG. 2. Section of Strata at the Locality where the *Pithecanthropus* Bones were discovered. *A*, area of growing plants; *B*, soft sandstone; *C*, lapilli stratum; *D*, level at which the skeletal remains were found; *E*, conglomerate; *F*, argillaceous layer; *G*, marine breccia; *H*, wet-season level of the river; *I*, dry-season level of the river. After E. Dubois.

have a total thickness of over 1,000 feet. The results of the Selenka expedition indicated that the so-called *Pithecanthropus* layer, containing bones of many extinct animals, owes its origin to the gradual working over of ash beds formed through eruption of great volcanoes near at hand. In the course of the eruption many animals were destroyed and the remains buried in ashes. Rain wash worked over the ashes and the entombed bodies of animals. The bones washed out were later accumulated at points where swamps or comparatively level stretches in the stream stopped transportation of heavy objects by slowing of the current.

The particular layer in which the *Pithecanthropus* specimens were discovered, was found by Dubois and by the Selenka expedition to contain a large number of remains of mammals, representing at least thirty species. These include the pre-elephant, or *Stegodon,* which is the immediate ancestor of the modern elephant, also cats, hyenas, rhinoceros, tapir, pig, hippopotamus, deer, buffalo and monkeys. Along with the mammals was a considerable variety of reptiles, among which were crocodiles, gavials, lizards, snakes and turtles.

The mammal fauna of the *Pithecanthropus* beds resembles in many respects that of the Java region of the present day, but practically all of the species are extinct. Certain forms, as *Stegodon,* are generally characteristic of the Pliocene, the second period preceding the present. The mammal assemblage as a whole is very close to that of southern Asiatic formations representing a stage near the close of the Pliocene, as seen in certain of the later levels of the Siwalik series in India. As mammal faunas are generally short-lived in the geologic sense, there seem good reasons for considering that the beds containing *Pithecanthropus* and the associated mammal remains were deposited at a period approximately the same as the late Pliocene on the early part of the next stage, the Pleistocene as recognized in other formations of which the age has been clearly determined (see Fig. 7).

Suggestions regarding age of the beds have also been made by Blanckenhorn on the basis of climatic conditions obtaining during accumulation of the deposits. Abundant plant collections secured in the formation containing *Pithecanthropus* indicate to practically all investigators who have examined them a much more humid climate than that now found in this region, and perhaps a temperature five or six degrees colder. Considering the Glacial Epoch to have been a time of relatively high humidity, Blanckenhorn believed the available evidence indicative of a time stage for the *Pithecanthropus* beds corresponding approximately to the first or Günz stage of glacial time, or near the beginning of the Pleistocene period.

NATURE OF REMAINS

Study of the remains of *Pithecanthropus* has been carried to an extreme of detail rarely reached in investigation of other known specimens. It is only regrettable that this work, so far as it has been done by workers other than Dubois, has been based largely upon casts of the originals rather than upon the specimens themselves.

The *tooth* first found is of extraordinary size, and quite different from the corresponding third upper molars of human

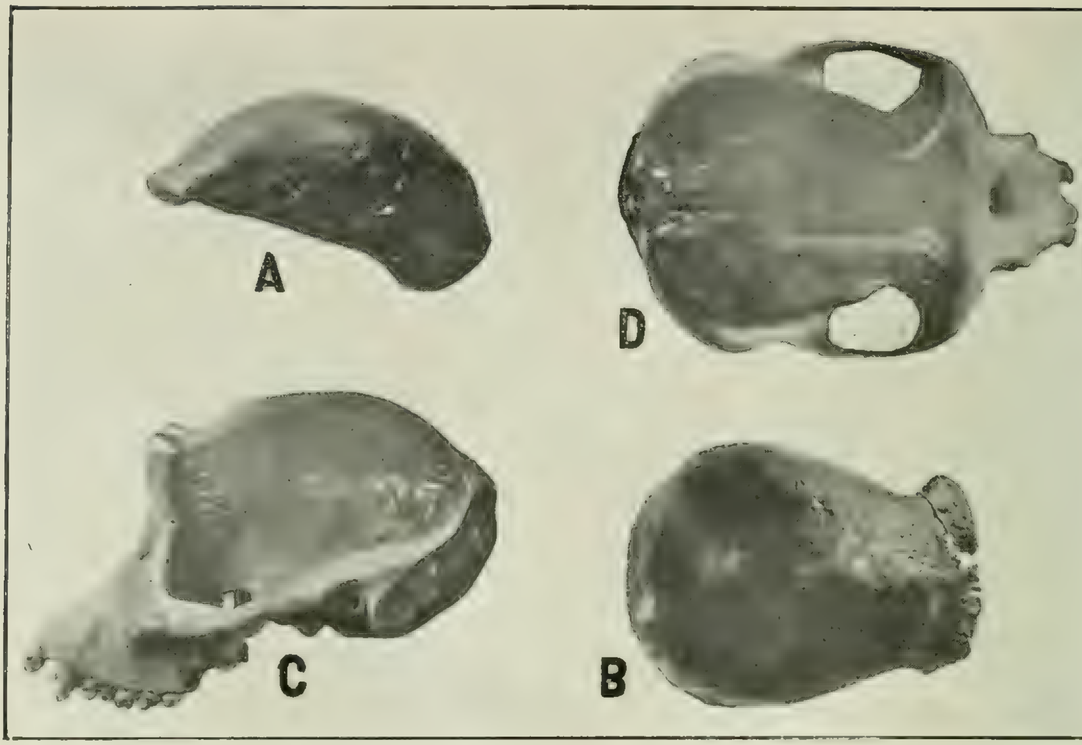

FIG. 3. *Pithecanthropus erectus*, Skull cap Compared with Skull of a Modern Chimpanzee. After E. Dubois. *A*, *Pithecanthropus* skull cap seen from the left side, ×1/3; *B*, same specimen seen from above; *C*, chimpanzee skull from the left side, ×4/9; *D*, skull seen from above.

beings. It either represents a large individual, or an individual with relatively large and heavy teeth.

The *skull-cap* has been examined from almost every possible angle of physical or mental vision by a great group of investigators, and is by common consent a most unusual type, bearing in general the characters of a human being, but more beast-like than any human species recent or extinct. The vault of the cranium is low, and the arch is flat both on the forehead and on the back of the skull. The eyebrow ridges are very prominent, as in the apes, and the skull is narrow behind the eyes. The brain capacity is lower than that of normal human types. Measurements of the cranial capacity given by Dubois have approximately 900 cubic centimeters, while the corresponding measurement of anthropoids rarely reaches 600 c.c., and of male Caucasian humans approximately 1,500 c.c.

From the interpretation of this specimen, it is evident that *Pithecanthropus* represents a type previously unknown in either the human or the anthropoid group. It differs from the apes in its larger brain capacity coupled with reduced musculature relating to the jaws. It differs from man in its lower brain capacity and more beast-like contour of the skull. If there is justification for the assumption that the large teeth pertain to the same individual as the skull-cap, there seems sufficient warrant for accepting an ape-like reconstruction of the face with the large protruding jaws needed to support large teeth.

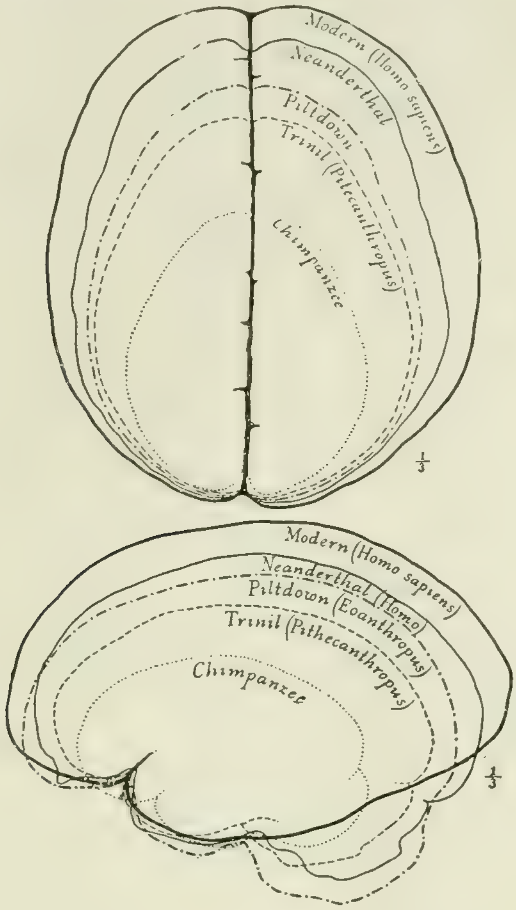

FIG. 4. Diagram showing Outlines of the *Pithecanthropus* Brain compared with that of the Chimpanzee and Certain Human Types. Upper figure, outline seen from above; lower figure outline seen from side. After Osborn, "Men of Old Stone Age," Charles Scribner's Sons.

Many restorations of the skull have been made, among which one of the most interesting is that by Dubois, showing

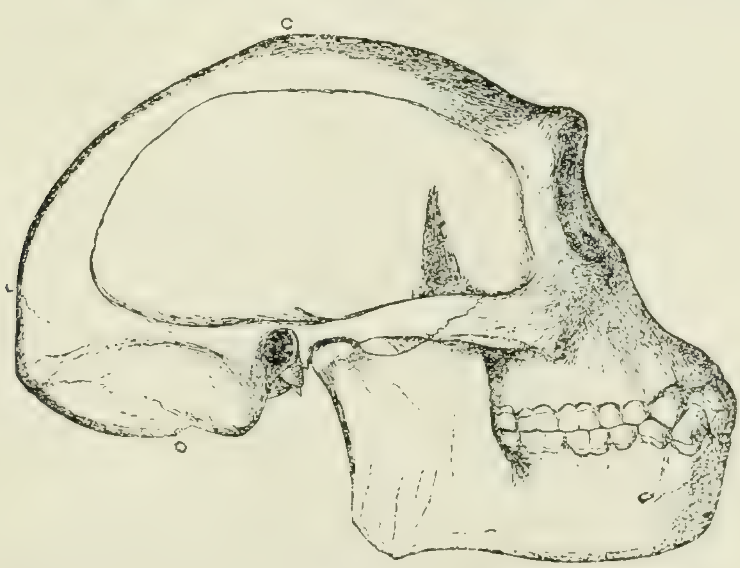

FIG. 5 Reconstruction of the *Pithecanthropus* Skull, ×1/3. After E. Dubois.

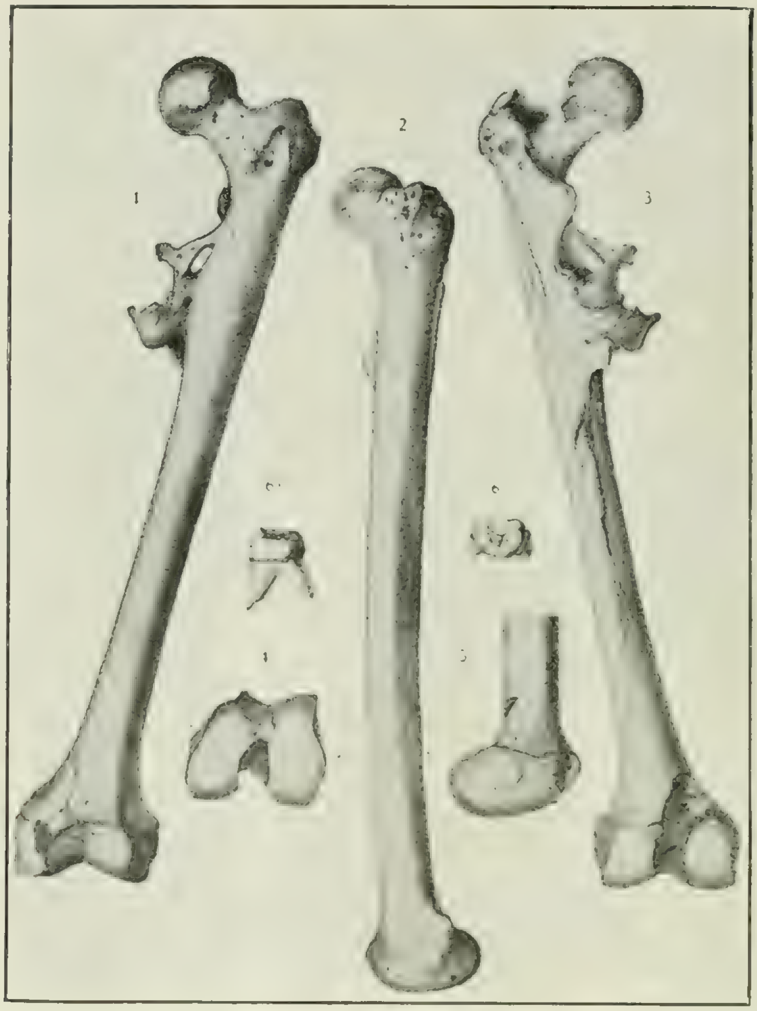

FIG. 6. Femur and Tooth of *Pithecanthropus*. 1, Femur from above; 2, from side; 3, from behind; 4, from below; 5, lower end from median side; 6, Right third upper molar from below; 6*a*, from behind. Much reduced. After Dubois.

the low-vaulted skull, prominent eye ridges, heavy jaws, and protruding facial region.

The *thigh bone*, found at the same level with the skull, resembles the corresponding bone of typical humans in some respects more closely than the skull resembles the cranium of human types. It approaches the human femur and differs generally from that of apes in its length, slenderness and straightness of shaft, as in other minor details. It is in fact more slender in some respects than the thigh bone of modern races. Resemblance to the femur of modern man is not, however, in any sense complete. Dubois has called particular attention to the more nearly circular cross-sections of the bone, and to distinct differences in certain important areas of muscle attachment. To a slight extent the peculiarities of the *Pithecanthropus* femur resembles those of the gibbon, but they do not correspond fully to gibbon characters.

This thigh bone cannot conceivably belong to an animal of the ape type. The form of the shaft and the nature of the articulations at the distal end are different from these features in apes. They show that the animal evidently walked with a degree of erectness comparable to that of typical humans, and that it must have possessed a length of limb and extent of stride in locomotion comparable to that of modern forms. This character of specialization for running or walking is not naturally combined with specialization of the anterior limbs for climbing, and we may safely assume shortness of arm like that of humans, and different from the type of limb in arboreal anthropoids.

Dubois and others have considered that the degree of deviation in form of the femur away from that of normal modern man and from the apes corresponds approximately to the extent of difference between the skull-cap of *Pithecanthropus* and that of both typical apes and typical men.

SYSTEMATIC POSITION

To the gratification of a large group of scientists, not long after publication of his memoir on *Pithecanthropus,* Dubois appeared with his specimens before the Zoological Congress at Leyden, where there occurred one of the most interesting discussions on the history of man that has ever taken place. Divergence of opinion as to significance of the remains lay largely in the question of classification. Five of the noted authorities, including Virchow, considered the animal to represent an ape; seven, including Cunningham, Lydekker and Topinard, considered it a man; and seven others, including Dubois, Manouvrier, Marsh and Haeckel, considered it a transition form.

With the wide knowledge of structure of man and of apes possessed by all of the eminent students whose opinions were expressed, it is clear that the essential difference lay in the definition of diagnostic characters of humans and apes. It is also evident that opinion of the group as a whole indicates the intermediate position of Dubois's find between typical humans and typical anthropoids. Centering upon the controversy over Dubois's specimens there has developed a discussion as to definition of hominid and anthropoid characters. There seems now to be practical unanimity of view that the essential distinctions lie in possession by man of somewhat greater brain capacity, erect position, length of limb, freedom of arm and hand from locomotion, and perhaps in possession of speech with sentence construction. These characters are contrasted with

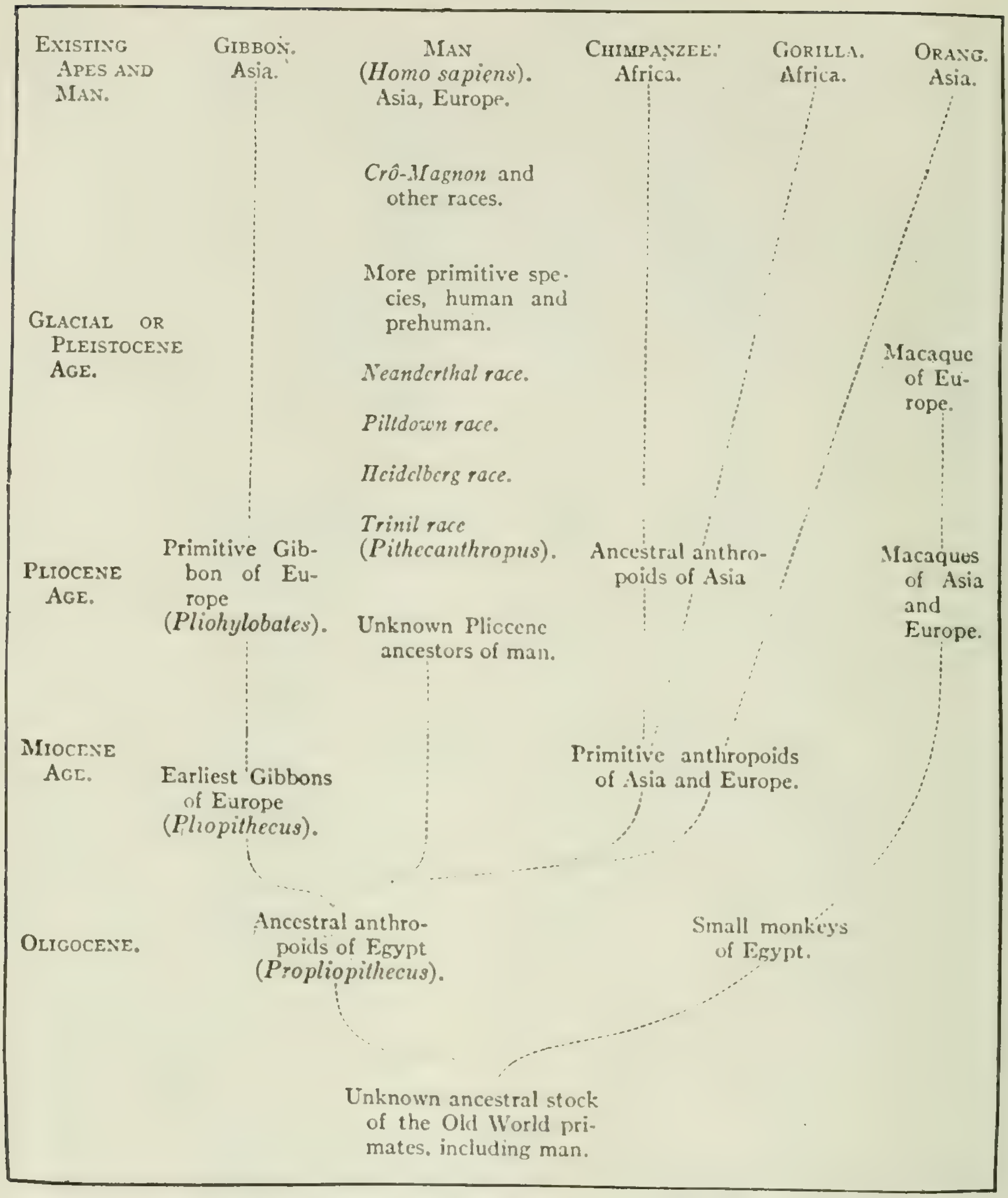

FIG. 7. Outline of the Evolution of Anthropoid Apes and Man. After Osborn, "Old Stone Age," Charles Scribner's Sons.

the smaller brain, more prominent face, relatively short grasping posterior limbs, and long anterior limbs used for climbing, seen in apes. Judged according to this definition, it is evident that Dubois's specimen represents a stage just above the middle territory between man and the apes. The animal seems particularly human in its limbs and pre-human, with strong anthropoid tendencies, in the skull.

RECONSTRUCTION

A reconstruction of the skeleton based upon skull-cap, teeth and femur of *Pithecanthropus* makes necessary the organization of an animal with upright position and long straight limbs. There can be little doubt that with this structure of limb the foot must have been much as in modern man and the great toe much enlarged. With such limbs, the anterior extremities would be released from the burden of work in locomotion and come to serve the head alone. The large teeth make heavy jaws and a prominent face almost a certainty. The small brain case and prominent rims of the orbits give the combination of pre-human and super-anthropoid characters required by the long-sought missing link. If, as Dubois assumes, we are correct in relating these three classes of characters in one skeleton, there is little required to give the picture of a transition form as visualized by those who have foreseen the discovering of an ancestor of man coming out of the animal world.

FIG. 8. Reconstruction of *Pithecanthropus* according to the Belgian Artist Mascré, under the direction of Professor A. Rutot. After Osborn, "Old Stone Age," Charles Scribner's Sons.

FIG. 9. Reconstruction of *Pithecanthropus* from the Restoration modeled by J. H. McGregor. After Osborn, "Old Stone Age," Charles Scribner's Sons.

Although the remains of the Java man are most unfortunately fragmentary, it is worthy of note that the long discussions which have focused on these specimens have left us with a remarkable unanimity of opinion as to the nature of the type. It is one of the most significant facts in the whole range of paleontological study, that these earliest known remains referred to the human group seem without question to represent the type farthest from modern humans and nearest to the anthropoids. The gap between the modern man and the modern apes is not fully bridged. It is perhaps worth stating that it will be difficult to define "fully bridging." The views as to what would constitute transition or "exactly intermediate stage" would probably vary with different investigators. It is, I think, quite certain that for the particular stage of geologic time in which it lived *Pithecanthropus* comes as near as we could well imagine to the expected intermediate form.

The Heidelberg Jaw

OCCURRENCE AND ASSOCIATED FAUNA

The second and perhaps the more important find of the two earliest known occurrences of remains referred to the human group is that known as the Heidelberg jaw. This specimen was obtained by Schoetensack, as the reward of twenty years persistent and continuous effort to learn whether traces of man might be found associated with the remains of extinct mammals at a locality in the Elsenz Valley not far from Heidelberg. From a sand pit Schoetensack had obtained many remains of extinct mammals of a stage sufficiently late in geological time to come within the assumed period of human evolution. Schoe-

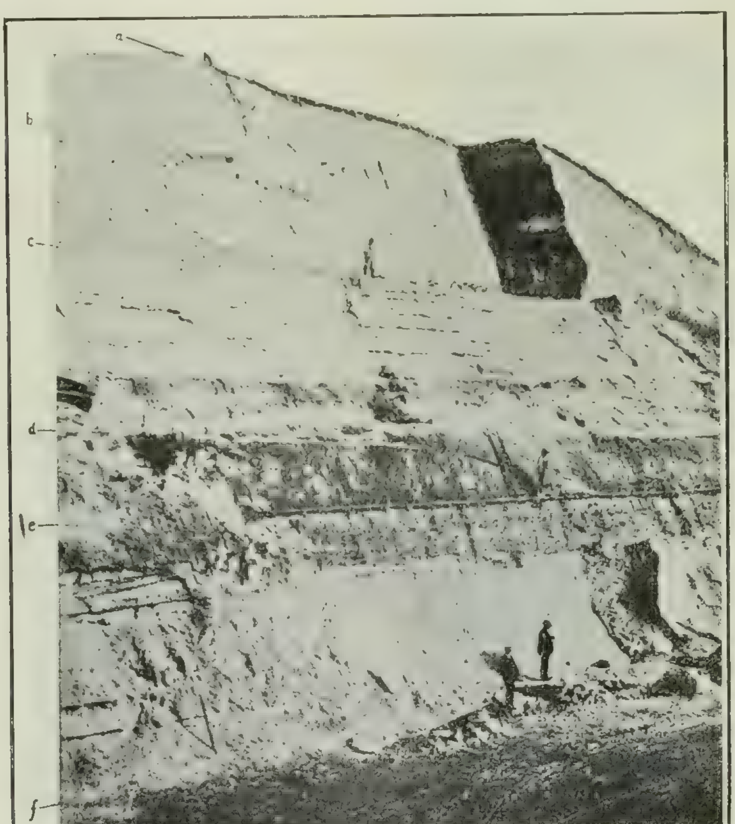

FIG. 10. Locality at which the Heidelberg Jaw was found, at a Depth of 79 feet below the Surface. The white cross in the lower right hand corner of the picture indicates the occurrence of the jaw. After O. Schoetensock.

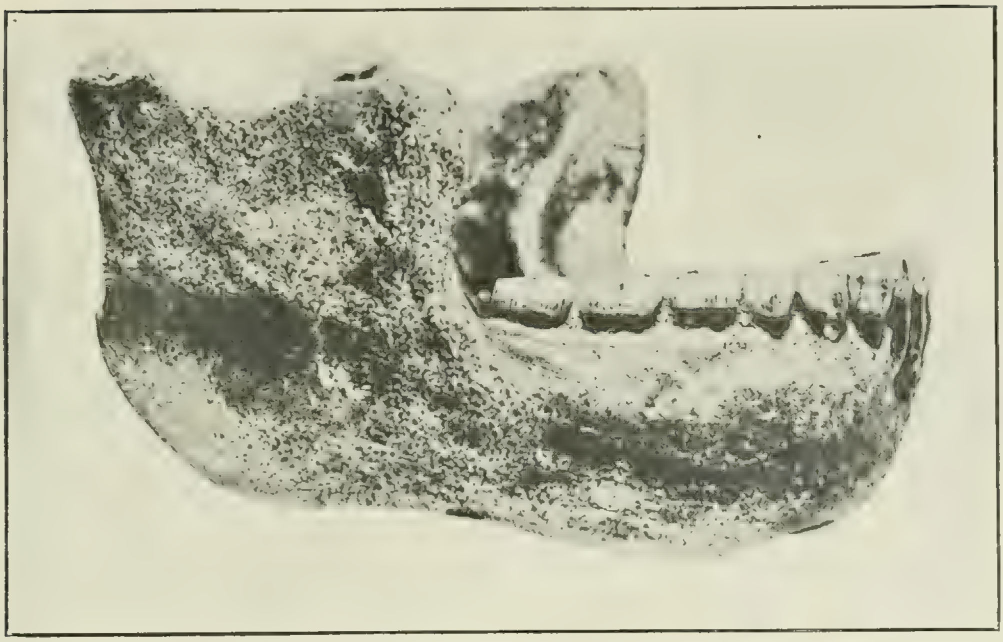

FIG. 11. Lateral View of the Heidelberg jaw, approximately two-thirds natural size. After Schoetensack.

tensack had repeatedly impressed upon J. Rösch, who worked at the pit, the importance of a possible find of human remains, and with the desirability of immediate and careful handling of any specimens suggesting man, should they appear. When in 1907 one of the workmen shoveled out a jaw of human type from a depth of approximately seventy-nine feet, the arrangements of long standing were favorable for rapid and trustworthy determination of the conditions of occurrence of this, one of the most remarkable known relics furnishing information bearing upon early human history.

The pit in which the famous jaw was found is cut into deposits consisting mainly of a formation known as the Mauer sands. At this locality the beds are about eighty-two feet in thickness. Between twenty-five and thirty feet of the upper portion of the deposits represent two formations known as loess. Below this upper section are the Mauer beds consisting mainly of sand and gravel. The human jaw was found only a little less than three feet from the base. The layer in which it was discovered was mainly gravel which was found to contain remains of extinct mammals characteristic of the Mauer beds. The condition of the undisturbed layer from which the jaw was taken leaves no room for doubt that all of the fossil remains, including the human jaw, were deposited at the same time with the sand and gravel making up this lowest portion of the formation.

The fauna found in the formation comprises not less than fourteen mammalian species, including the Etruscan rhinoceros, a species of horse, a primitive elephant (*Elephas antiquus*), a large lion (*Felis leo fossilis*), and remains of bear, deer, pig, and bison.

Schoetensack held that the Mauer fauna showed relationship to the early glacial or inter-glacial forest bed of Norfolk, as also to the Pliocene. The rhinoceros and the horse were considered especially significant of the earliest Pleistocene or Pliocene. Schoetensack placed particular stress upon the possibility that the jaw was the earliest authentic skeletal representative of the human group. Other investigators have considered the formation in which the Heidelberg jaw was found as considerably later and representing the second or Mindel-Riss inter-glacial stage.

DESCRIPTION OF REMAINS

The Heidelberg jaw undoubtedly constitutes one of the most interesting remains of early man thus far discovered. In comparison with all modern human types, it is characterized by its unusual size, lack of protruding chin, great strength and thickness of the body of the jaw, and unusual width of the area for the attachment of the muscles used in mastication. It is also characterized by the extraordinary form of the inner side of the anterior region of the jaw in an area marked by the attachment of certain muscles having an important relation to movement of the tongue in speech. The teeth are large, but not relatively large compared with the size of the jaw, and are notably human in practically all characteristics. While the jaw without the teeth might not have been called human, the teeth without the jaw would certainly have been assumed to represent a human type not differing greatly from known species.

The teeth are characterized by strength of the roots and large size of the pulp cavities; but considering their relation to the peculiar primitive type of jaw in which they are situated, the most striking characteristic of the dentition is probably the small, distinctly human canine. Comparison of the human dentition with that of the apes brings out the fact that humans are distinguished by limitation of the canines to such dimensions that the crowns of these teeth show approximately even length with those of their neighbors. In the apes, as in many other groups of mammals, the canines are very prominent, projecting far beyond the level of the neighboring teeth, and having an important function in tearing food or in fighting. It has been assumed that primitive humans and intermediate types between man and other mammals would naturally be characterized by somewhat larger canines than those of modern species. In a jaw showing the massiveness, strength and primitiveness of the Heidelberg specimen, it would be natural to expect a canine of somewhat greater size than that of modern human types, whereas, as indicated, this tooth is here reduced to dimensions comparable to those of advanced modern types. It seems, therefore, that reduction of the canine to dimensions comparable to those of other teeth in the front of the jaw is one of the most significant characteristics of the early human type.

As shown in comparison of an Eskimo, the Heidelberg jaw, and a chimpanzee, the combination of characters in the Heidelberg specimen is more like that of the anthropoids than is the combination known in other forms referred to the human group. While the dentition in general is distinctly human, the size of the teeth, compared with those of many modern types, with the heavy roots and wide pulp cavities present characters which point toward an ancestral type resembling the anthropoids in some measure.

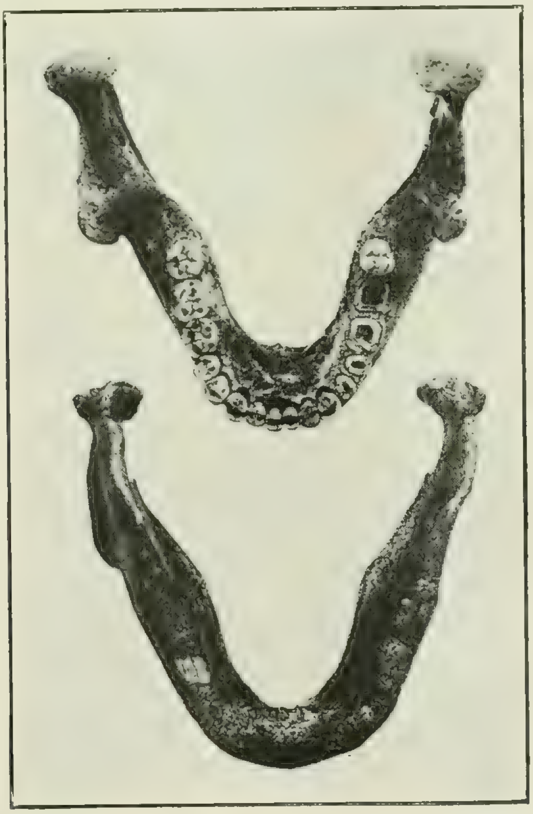

FIG. 12. Upper and Lower Views of Heidelberg Jaw, slightly exceeding one half natural size. After Schoetensack.

FIG. 13. Comparison of Heidelberg Jaw, in the middle of the picture, with a Modern Anthropoid to the right and an Eskimo to the left. After Osborn, "Old Stone Age," Charles Scribner's Sons.

In the configuration of the inner side of the jaw, there are strong evidences indicating that the musculature was different from that of modern man endowed with peculiar characters of the tongue related to speech.

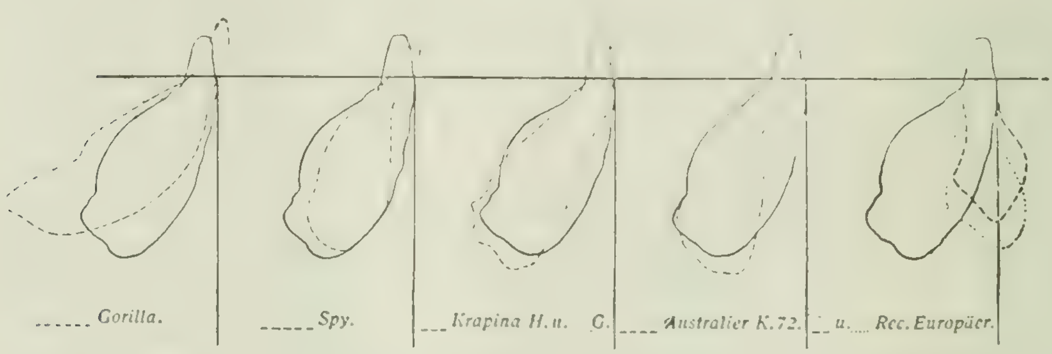

FIG. 14. Comparison of Vertical Sections through the Chin Region of the Lower Jaw. The sections of the Heidelberg Jaw are drawn in heavy line. The jaws with which comparison is made are indicated in broken lines.

The upper dentition and skull of the Heidelberg man have been reconstructed with great care by Dr. J. H. McGregor, and show a form resembling that of *Pithecanthropus* in many respects, but somewhat less ape-like. The teeth are smaller than those of *Pithecanthropus*. The face was probably less prominent and the brain capacity presumably greater.

SIGNIFICANCE OF THE HEIDELBERG JAW

The stratigraphic position of the beds from which the Heidelberg or Mauer jaw was obtained has not been questioned. The associated fauna has been known at a considerable number of other localities, so that the occurrence of this specimen is defined as that of a form living in middle or early Pleistocene time, with certain suggestions of Pliocene stage. The age of the *Pithecanthropus* specimen has been the subject of much discussion, and is considered by some to represent a stage only a little earlier than that of the Mauer jaw. The association of the *Pithecanthropus* skull-cap, teeth, and femur as parts of one individual or one species has also been questioned. While it may be that the Java specimens represent the same individual, it is also within the range of possibility that they represent two or three distinct types. Though great interest at-

Fig. 15. Restoration of the Heidelberg Man by the Belgian Artist Mascré under the direction of Professor A. Rutot. After Osborn, "Old Stone Age," Charles Scribner's Sons.

taches to the discovery of *Pithecanthropus*, and to the speculations concerning the nature of the creature or creatures represented by this find, it is possible that the unquestionably primitive Mauer jaw, occurring in undoubted association with an early Pleistocene fauna and in a somewhat more definite geological situation, represents the most important and perhaps the earliest of the known human remains.

Possible Traces of Artifacts Produced by Earliest Known Humans, the Eolithic Culture

Assuming that two of the essential characters separating the hominid group from the anthropoids are found in the free-

SYSTEM OF CHRONOLOGY FOR THE STONE AGE

(ADAPTED FROM RUTOT)

RECENT			NEOLITHIC	*Present fauna.*	Robenhausian. Campignian and Tardenoisian. Tourassian.
QUATERNARY	FOURTH GLACIAL PERIOD	Retreat.	PALEOLITHIC PERIOD	*Fauna of the Reindeer.*	Tarandian Industry.
		Advance.			
	THIRD GLACIAL PERIOD	Retreat.		*Fauna of the Mammoth (Elephas primigenius).*	Eburnean Industry.
		Advance.			
	SECOND GLACIAL PERIOD	Retreat.			Mousterian Industry.
		Advance.			Acheulian Industry. Chellean Industry. Mesvino-chellean or Strépyan Industry (Strépy, Belgium).
	FIRST GLACIAL PERIOD	Retreat.	EOLITHIC PERIOD	*Fauna of Elephas antiquus.*	Mesvinian Ind. (Mesvin, Belgium). Reutelo-mesvinian or Mafflean Industry { Maffle near Ath, Belgium.
		Advance.			Reutelian Industry (Reutel, Belgium).
TERTIARY	PLIOCENE	Upper.		*Fauna of E. meridionalis*	Ind., Cromer Forest Bed (Norfolk). Industry of Dewlish (Dorset). Industry of Saint-Prest (France).
		Middle (Glacial.)		Industry of the Chalk Plateau (England).	
		Lower.			
	MIOCENE	Upper.		*Fauna of Dinotherium*	Industry of Puy-Courny (France).
		Middle Lower.			
	OLIGOCENE	Upper.		*Fauna of Aceratherium*	Industry of Thenay? (France).
		Middle Lower.			
	EOCENE				

FIG. 16. System of Chronology in the Stone Age. After MacCurdy.

ing of the anterior extremities to serve the head and in the development of intelligence to make possible a wide variety of uses for the anterior extremities, one naturally considers the making of implements or artifacts as a characteristic which should be distinctive of humans. Question has therefore arisen whether the *Pithecanthropus* and Heidelberg types had reached a stage at which natural objects were regularly worked into artificial forms.

The Selenka expedition secured along with other fossil remains found in the *Pithecanthropus* beds of Java, a considerable number of bone fragments showing peculiar fracture and worn points suggesting use by primitive man. Blanckenhorn and others who examined these specimens carefully were, however, of the opinion that they might have been produced by fracture of bones carried in a stream or broken by beasts, and that they were not certainly to be attributed to the work of the hominid represented in these strata.

By far the largest representation of evidence suggesting the use of implements by primitive man-like forms near the period of transition from ape to man, is that furnished by the great quantity of flaked flints obtained from strata ranging from Pleistocene down through the late and middle Cenozoic formations of western Europe. These specimens, representing what have been assumed to be the first artificial implements, have been designated as *eoliths*, or the work of the dawn period of implement making. Especially through the work of Rutot,

FIG. 17. Eoliths from Belgium. Approximately three-fifths natural size. After MacCurdy.

a considerable variety of flint forms coming from deposits ranging back through the period of *Pithecanthropus* and the Heidelberg man to older time stages have been interpreted as early efforts at preparation of artificial tools.

It is to be assumed that the earliest stone implements used by man were fragments which in their unmodified form were somewhat better fitted for the use of his hand than other more unwieldy or irregular pieces. Presuming that man early learned the cutting power of a rock, it is probable that fragments with sharp edges naturally produced were used at times in place of those with rounded contour, and that specimens thus used and fractured by use may have been found to have an advantage over weathered rocks naturally broken. This may have led to artificial preparation of such broken stones. There should, therefore, be an intermediate stage between unworked natural objects and the earliest tools purposely produced. From the materials representing this type, it would be exceedingly difficult to obtain evidence as to the way in which the objects were formed.

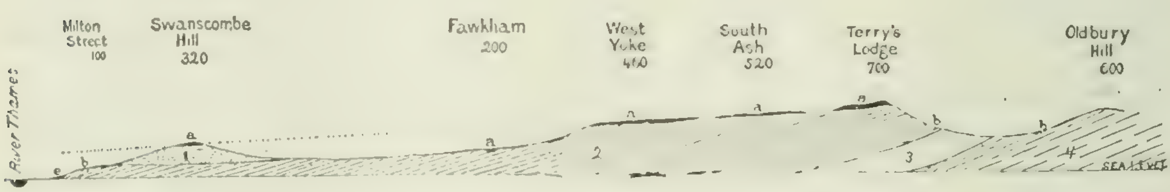

FIG. 18. Section from the Thames to Oldbury Hill near Ightham Kent, England. After MacCurdy, adapted from Prestwich. 1, Tertiary; 2, Chalk; 3, Upper Greensand and Gault;; 4, Lower Greensand. *a*, Red clay with flints—eoliths. *b*, Upper valley gravel—palæoliths. *c*, Low-level valley-gravels—palæoliths.

No scientific controversy in Europe in the last decades has been more warmly contested than that over the artificial or non-artificial character of the eoliths or broken flints from formations of approximately Pliocene age, and in the zone in which one might expect the beginnings of implement making.

Among classic localities for these flints is that of the Kent Plateau, where, near Ightham in the south of England, Mr. Benjamin Harrison through many years has collected a wide range of flint forms from deposit assumed to be of Pliocene age. These eoliths occur in a red clay formation which lies across the edges of several upturned formations of considerable antiquity. Through this plateau there has been cut the valley of the Thames River. In sculpturing out the modern topography, various stages in the cutting of the valley along the streams have left terrace deposits on the banks, in which considerable numbers of flint implements have been found. In the lower levels bordering the valley, the flints represent stages in the history of implement making corresponding to the middle Pleistocene of western Europe. In the upper levels representing the stage before the cutting of the valley, eoliths are obtained and the Pleistocene implements are not represented. There is, then, a historic sequence in the implement making of this region beginning with the stage of the eolith of the upper plateau, and grading through the more advanced stages of implements in the lower terraces.

The eoliths of the Kent Plateau correspond to a period not later, and probably earlier, than that of *Pithecanthropus*, and certainly older than that of the Heidelberg man. It is not improbable that flaked flints of this nature were used by both of these primitive human types. Whether the flints of the Kent Plateau were implements, and whether their origin was through artificial human production is difficult to determine. The fact that they grade insensibly into flaked flints of a type which may have been produced without the intervention of man, does not prove that their form was not due to human influence, and that they were not actually used by man. On the other hand, there is much evidence to indicate that many of the flints of these eolith beds may have been formed without human assistance.

Conclusions Regarding Significance of Earliest Hominid Remains

In concluding this phase of the discussion relating to the earliest traces of beings of our human group, it may be desirable to view in the large the data thus far assembled.

We have seen that remains of man-like forms are not limited to deposits of the present period nor are they found in all formations of the geologic succession. We find the earliest evidences indicating the presence of man occurring at that particular time, and not before the time, when evolution of the group of animals most closely resembling us had reached a stage near to the human type.

We find the earliest humans represented as a part of the normal life of the earth in a period so remote that in our calculation of its date a thousand years seems only as a day. *Pithecanthropus* and the man of Heidelberg were long dead, and had become ashes of a bygone age, before the world saw the beginning of many extended series of events, which changed the form of continents, shifted the earth climate back and forth from arctic to temperate in changes of the Glacial Epoch, and passed over the earth long processions of living generations each in turn enjoying its hour of geologic time and fading out into the night of history. Although of these most ancient humans the earliest preserved traces are very faint, we find them adequate to show that at the time in which they lived our race was represented by beings set off from other primates by their erect bodies, long-striding limbs, hands that were free to build, and a brain that began to plan. And yet we find these forms more beast like and more anthropoid than any type of man at any later time.

So far as our evidence goes, it meets the requirements of those who assume the emergence of man from the animal world in the same manner in which innumerable other organic types have arisen in the long life record as we know it.

The reading of the full story of the advent of man is still to come, and the task of deciphering it will go on into coming centuries. With this must proceed also interpretation of the subsequent stages of man's growth or evolution, of which a brief account will be presented in a later paper.

THE MEASURE OF EXCELLENCE IN SCIENTIFIC ACTIVITY

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THE fundamental scientific activity is that which is expended in the search for truth, in discovering and establishing what can be made sure by experiments or by undisputed logical processes convincing to all who understand their nature. But truth has value only as it exists in the minds of men and women who procure from it practical or ideal benefits for themselves or others. Consequently scientific workers must see to it that a suitable portion of the body of truth is made widely known and is preserved for future generations. This calls for the work of the teacher and for the publication of the results of research. It also demands a certain measure of educational propaganda, at least in a country where scholarly traditions are just being developed, in order to create and maintain the proper interest in scientific truth and an appreciation of its values. Let us consider first this essential secondary part of scientific activity, the part which has to do with the dissemination of results once attained.

In a country in which research is as new as it is in ours and in which no controlling spirit of tradition is in existence for the maintenance of ideals, there is danger of thinking too lightly of breaking up the research work of an active man by assigning to him editorial duties in connection with periodicals both for the record of scientific achievement and for the work of educational propaganda. Committees of scientific organizations charged with the duty of procuring a man or a group of men to do such editorial labor are inclined to place an undue emphasis upon the work for which they are temporarily responsible and to seek appointees for it without a sufficiently keen realization of the needs of science as a whole. Unfortunately it sometimes requires actual experience with editorial work for a research man to realize how fundamentally it will break up the continuity of his thinking; and through this failure to see the true situation beforehand he may enter upon a labor in which he will be compelled to look upon himself as one of the principal offenders in the development of a spirit of thinking lightly of breaking up research work, although there is nothing in which he believes more ardently than in the value of ascertaining new truth.

The aptitude required for research and that for editorial labors are distinct in their character and there is no reason to believe that the possession of the one implies that of the other. In fact it is rare to find the two prominently present in the same individual. There are two types of things to be accomplished and two types of men from whom are to come the persons to accomplish them. In advancing a matter of secondary importance, essential though it is, we should be careful not to hinder the more vital work of research. Neither of these two things can be separated from the general cause of science. Moreover, we must keep in mind also the welfare of the individual who is asked by his colleagues to undertake any particular definite piece of work. To be sure, the cause of science is of sufficient importance to justify a considerable sacrifice on the part of one person in order that the general cause may prosper to the best advantage, unless that person is one of the most vital thinkers among his colleagues. Such a one should be left entirely undisturbed. In all cases we are in duty bound to find for each particular labor to be assigned a man who can do it without departing too widely from the things in which he is naturally interested and to which he is temperamentally adapted.

It is essential to our best welfare not only that a correct judgment of values shall be maintained among practised scientific workers but also that the younger men as they come along shall be led to a proper emphasis of values. There is a tendency in some quarters to magnify the importance of editorial work and to esteem it as the basis of as high preferment among one's colleagues as almost any service that could be rendered. There is danger that this error shall be particularly insidious in its influence upon the younger scientists; and it needs therefore to be brought into the light of day where it can not live. It must not be true, and we must not allow the feeling to develop, that it is likely to be of personal advantage to our scientists for them to give up a significant portion of their creative labors in order to perform editorial or any other duties of a secondary sort. Creative work alone produces the more fundamental values. It would be injurious to the cause of science in our country if anything should be done to create the feeling that it is a light matter to lay down research work from any considerations whatever having to do with less vital matters. Let us make sure that there is nowhere in our scientific atmosphere a source of infection breeding such dangers to our young scientists.

In certain subjects, as for instance that of pure mathematics, there is at present a great lack of scholarly and sufficiently complete expositions in English of the matters of central importance. The number of mediocre or very elementary books is great, in fact so great that it seems to be desirable to lessen the future output by means of a definite public opinion disapproving the appearance of books not having a sound scientific reason for their existence. But it is a distinct service of a high order, above that of editorial labors, to produce scholarly expositions from a sufficiently advanced point of view.

It is therefore important that we shall encourage the production of such books. Two essentials will have to be supplied: it requires well-trained scientists of keen insight to prepare the manuscripts; then there must be publishers willing to invest capital in the enterprise in order to put the book before the public. The latter need will take care of itself and writers will be encouraged to supply the former if such books begin to have a sufficient number not only of readers but also of purchasers. We need to develop the disposition to distribute more widely in public libraries the scientific books of higher grade and the inclination on the part of scientists to enlarge their private libraries. The existence of a large number of discriminating buyers would certainly stimulate the production of the books desired. To buy as many important books as you can use with profit and not as few as you can get along with is to do good to yourself and also to render service to the cause of science.

Nearly all scientists in America have superimposed upon their other activity that of the teacher. Unfortunately the time and energy of not a few men of originality and insight are too largely consumed in elementary instruction which might well be given by persons of less training and sometimes with advantage to the learner. Thus we might release the men of other temperament for that different work which can be performed by only a relatively small number of people. But it is desirable, from the point of view both of the learner and of the scientist himself, that lectures on advanced topics shall be given only by men actively and vitally engaged in research. To the former comes the value of contact with insight, power, and enthusiasm; to the latter, the inspiration of seeking a living exposition by means of which a new mind shall acquire a previously unrealized power.

In order that teaching shall proceed to the best advantage there must be some organization by means of which the various parts of the work shall fit together; and this calls for administrative officers. Unfortunately the work of these in American institutions is magnified beyond its deserts, especially in some of the newer universities which only lately have laid aside the garments of the college. In such institutions many hold-overs from the old régime are to be found, both as heads of departments and as other men of the more advanced rank in the university. Some of these are such that no word of criticism is to be spoken against them; and some are at the other extreme without the grace to remove themselves from an impossible position. These evils do their greatest harm perhaps in operating to make it difficult for the youths to form correct judgments of value.

As science develops it is of increasing importance that we shall prepare histories of it in the form likely to be made useful in the several ways in which they may be of value. There are three distinct primary needs which may be supplied by histories of science, namely: To enrich the general culture and intellectual life of educated people; to enable a scientific worker to quickly orient himself in a chapter of a science so as to proceed most readily to a detailed mastery of its literature; to enable a scientific worker to ascertain with completeness what has already been attained in a given subject.

To serve any one of the three purposes indicated requires a very different treatment from that needed in the case of the others. The literature at present in existence is totally inadequate in each of the classes; and it seems now likely to remain so for some time. For a few well-confined subdivisions of the several sciences, and for such alone, have we sufficiently comprehensive histories for the workers in particular sciences; and nowhere is there yet made suitable provision of historical material in science for the needs of general culture. In this portion of the history of thought, therefore, is to be found a great opportunity for service to the cause of science and of human progress. The work to be done calls for full training and for insight of a high order.

But the primary and most fundamental requisite for general scientific progress is discovery and verification of new truth. After the worker has been found who may enter upon this labor the next essential is his acquisition of knowledge in the domain in which his energies are to be expended. He must be familiar with a certain measure of the results obtained by his predecessors. The only approach from our side to the boundary of knowledge is along a path which leads through fields of truth already explored; and he who is unable or unwilling to travel such a path will waste in fruitless endeavor whatever energy he expends in trying to penetrate into the unknown.

But the path along which he approaches the boundary of knowledge may vary greatly with the individual thinker, being affected both by his temperamental aptitudes and by his total measure of power. One will see by an almost unerring intuition the significance and bearing of a given restricted body of doctrine as soon as he is in possession of the truth which constitutes it. Another must know in detail the various related doctrines before he can come to a realization of the import of the first one. It is clear that two aptitudes as widely separated as these demand distinctly different means for the acquirement of truth and for the realization of further progress.

Perhaps the matter may be clarified by a figure. The man of less native force will probably find it necessary to approach the boundary of knowledge along a spiral path which starts from some place in the interior and winds round and round repeatedly, always coming a little closer to the boundary and approaching it asymptotically. This method requires the maximum time and energy for reaching the neighborhood of unexplored territory. Moreover, the line of progress is along a path not far removed from a parallel to the boundary. Consequently the component of momentum in a direction perpendicular to the boundary is small, at least in those places where the boundary is more regular. One who proceeds along a spiral path of learning will therefore have the greatest facility for penetrating the unknown if he finds a narrow cape from the continent of ignorance projecting far into the ocean of acquired truth; and here he will carry on explorations of value, but will hardly be able to open a new region of large extent.

It is obvious that discoveries originating in this way tend to round out and make regular the total body of known existent truth. But it is unlikely that they shall bring within our grasp any body of truth of essential novelty. It would seem therefore that the spiral method of approach to the boundary of knowledge is best suited to those prospective researchers who are of mediocre ability; and that others, having first acquired a suitable general fund of knowledge, should then proceed more directly toward territory as yet unexplored.

This calls for what may be termed the radial method of approach to the boundary of knowledge, that in which one proceeds along a path more or less nearly normal to that boundary. We suppose that one who is to go in this direction shall have first acquired a suitable preliminary acquaintance with the more fundamental matters in his particular science as a whole. Moreover he must be one of those of greater native force or he will be lost in proceeding directly far into unfamiliar territory. But if he has the proper central fund of information and the requisite native force of intellect he can proceed along such a radial path with increasing momentum. Now, practically the whole of this momentum is in a line perpendicular to the boundary and consequently will serve as a means of breaking through and perhaps of penetrating far into previously unexplored territory.

It is obvious that discoveries arising in this way have the greatest likelihood of opening up new regions of vast extent; and they may even issue in the introduction of fundamentally new ideas. Perhaps our greatest progress is realized from an assault of this sort upon the unknown, one along a fortunate direction chosen by dumb intuition or by a prevision of the character of the advance to be anticipated.

The advantages of radial approach are not altogether denied to those who are restricted by inherent limitations to the spiral method of acquiring known truth. After they have come into possession of a certain general body of doctrine they may select out one line of development in it and proceed through this in a radial direction to the boundary of knowledge and thus have the advantage of a realization of the full momentum of their progress. But they will lack the zest and enthusiasm which characterizes a first view of beautiful truth, and this will usually dim their insight and preclude the greatest conquests. Nevertheless, it must be admitted that some of our very important discoveries are made in this way, particularly among those which are intimately associated with bodies of doctrine for a long time in a state of high development.

In estimating the measure of excellence in scientific activity one can not leave out any fundamental element in the culture of mankind. Our development is as a whole and not in fragments. To be sure, the growth at any one moment may be in spots; but there is a constant interaction among the various parts and a consistent evolution of the whole. One portion of the body of truth can not develop far while all other portions are in a resting state. Each needs the stimulation which comes to it from discoveries beyond its own boundaries and the encouragement consequent on seeing the fruit which itself yields in other domains. Let us therefore consider the values arising from the interaction of science with other general divisions of thought.

Among certain scientists there is a tendency to underestimate the value of philosophical thought owing to the influence of a subtle error in logic arising from reaching a conclusion without formulating wholly in consciousness the argument by means of which the conclusion is attained. Among these scientists it is the custom to reckon as a part of science any well-established results which have met what seem to be the appropriate tests of truth, regardless of how these results are first obtained. Therefore, whenever any range of thought has reached a stage of development at which it is able to exhibit definite conquests it becomes, at least in the region of these conquests, a part of the general body of science.

Now in philosophy there has always been much that is speculative. But if philosophy should get its feet on solid earth and attain a conquest definitely achieved these same scientists would take the achievement out of the realm of philosophy—and perhaps rightly so—and annex it to the domain of science. Such a procedure seems rather hard on philosophy; but it might be passed over in silence if it were not followed by an injustice which it is made to support.

These same scientists when they have taken out of philosophy every definite conquest and transferred it to the realm of science, then intimate that philosophy is without essential value; and to drive this intimation home with compelling power they demand with gusto to know what is the single definite achievement belonging to the domain of philosophy, whereas, according to their accepted principles, any definite conquests made by philosophy would pass from philosophy into science in the act of becoming definite. Thus they draw the line of demarcation between science and philosophy so that all definite conquests lie in the domain of the former and so that only speculative or unestablished opinions belong to the latter, and then they decry philosophy as useless because it contains no body of well-established truth as part of its permanent possession. This procedure is unscientific and unjust.

In order that philosophy, even so restricted, may be denied a place of importance in the development of scientific truth, one must show not only that it has made no permanent conquests but also that it has failed to assist materially in preparing the way for the advancement of science. This latter can hardly be maintained even by the most narrow devotees of science; for it is notorious that the atomic theory and the theory of evolution, central as they are in all modern natural science, were at home in philosophy for generations before they took a form in which they might be used in the domain of more exact truth. Their presence for a long time to the thought of mankind was one of the essential prerequisites to their use in connection with knowledge obtained by experiment and observation. Thus two of the most fundamental conceptions in modern science, one having to do with non-living and the other with living objects, have come into their own with the assistance of speculative thought.

From many points of view we are forced to a consideration of the question as to where philosophy ends and science begins or to the conclusion that there is no dividing line and that the two names represent different aspects of the same thing. Now it seems clear that there is a difference in character between the extremer speculations of philosophy and those parts of science which are so far advanced as to furnish means of precise and accurate prediction. And if there is this essential difference in the more widely separated parts of the two bodies of thought it appears that we must grant them to be different even though at some places they may approach so closely together as to have a common boundary.

Assuming, then, that there is a valid distinction, let us raise the question in some such concrete form as the following. The early statements of the atomic theory of matter (among the Greeks) are clearly speculative in the highest degree and as such belong to philosophy; in our day the atomic theory is characteristically scientific, having the most intimate connection with a large body of experimental results. In the development of this theory where does philosophy end and science begin? The question has a two-fold aspect. Historically, when did the exclusively speculative character of the doctrine take on a scientific form? and to what extent had the theory advanced historically when one should first begin to call it scientific? Logically, what was the state of affairs when one may properly begin to speak of the theory as scientific?

To follow out these questions with care would probably throw considerable light on the fundamental problem as to the relation between science and philosophy. One ought if possible to establish certain definite criteria or sets of criteria of such sort as to distinguish with clarity between that which is scientific and that which is philosophical, except possibly for a narrow ambiguous band lying along the common boundary. Thus, if a theory has reached a stage where it enables us to predict with accuracy certain definite phenomena, there seems to be no doubt that it should be classed as scientific. If this quality is absent should we say that the theory is still in the less advanced stage of philosophy? Or, should we make our test for scientific character less stringent and say that the theory, whether established or not, belongs to science if it is so formulated as to enable us to conceive definite means of subjecting it to experimental test? These are questions on which as yet there seems to be no general agreement.

In science itself there are two bodies of doctrine so distinct in some of their leading characteristics as to be often opposed one to another, namely, natural science and mathematics. In fact, one often has in mind the former when he speaks in a general way of science, using no qualifying word. In such wise have we used the term in the foregoing study of the relation of science and philosophy. Let us now still more definitely make the separation and proceed to a consideration of the relations between natural science and mathematics.

Some workers seem to resent the interference of mathematics with their comfort in the conclusions of descriptive science and its demands that observation shall be reduced to measurable elements and the laws of nature be expressed in mathematical formulas; other thinkers believe that natural science is real science only in so far as it is mathematical, that it is only through mathematics that true science can be understood, and that without mathematics no science can develop to maturity. One delights in observation and the record of facts, believing that he has understood a class of phenomena when he has given a general description of their relations, order and connections; the other considers the mathematical formula as "the point through which all the light gained by science must pass in order to be of use in practise."

It is clear that observation alone is insufficient for the understanding of a physical fact. Liebig has formulated three conditions which he considers necessary:

> We must first study and know the phenomenon itself, from all sides; we must then determine in what relation it stands to other natural phenomena; and lastly, when we have ascertained all these relations, we have to solve the problem of measuring these relations and the laws of mutual dependence—that is, of expressing them in numbers.

On this view we should have, apart from measurement and hence apart from mathematics, no science except in the preliminary stage preceding the considerable development of any chapter. Some have gone further and have maintained that there is no science whatever except that which stands definitely and clearly on measurement, that the essence of science in the whole and in every part is measurement and solely this.

But this extreme view is not upheld by the position of modern science. There is a significant chapter of chemistry, for instance, in which precise results of a definite character are obtained under the guidance of a theory in which something essentially different from measurement holds the central place, namely, the linking and spatial arrangement of atoms in the molecule. There is a difference of properties accompanying identity of molecular formulæ where we are forced to admit even the same atomic linking and can ascribe the existing difference only to unlike positions of atoms in the molecule. This is the central notion in the chapter. It has been formulated so definitely and the facts of experiment have been associated with it so closely that there can be no doubt of its correspondence with some esential reality as the main feature involved. It is obviously not in the same class of ideas with measurement.

This leaves unanswered still the question as to whether a self-contained body of well-developed scientific truth can be isolated which has been established and may be expounded without essential use of the method of measurement. It will readily be admitted that some of the preliminary work in the creation of a science consists in the description of phenomena and their analysis as to qualitative aspects. But it seems that we can not bring any chapter of science to a resting state of relative completeness until we have laid the basis for it deep on a foundation of accurate measurement. In the example cited from stereochemistry, for instance, we have in the advanced stages a portion of theory depending primarily on considerations of relative positions in space; but antecedent to the development of this portion of the theory and necessary to its creation and even to an understanding of it is a large body of doctrine resting on detailed measurement.

It appears, therefore, that no science can come to a relatively high state of development until it has been made to rest on a mathematical foundation. Those who insist most strongly on the kinetic or mechanical view of nature appear to believe that physics and chemistry, the basic sciences of natural phenomena, "are destined to become ultimately merely chapters in dynamics as the doctrine of mechanical motion." But probably Maxwell is nearer the heart of the matter when he insists that a physical theory should be at the same time both mathematical and physical.

It seems that no body of thought has at the same time been of more importance in human progress and been criticized more freely than the science of mathematics. Much of this criticism appears to be good-natured and to amount to but little more than a quasi-humorous way of expressing the critic's own unashamed ignorance. At first sight one might treat this as harmless; but from the point of view of the general interest it can hardly be passed over in such a way. How this ignorance is to be overcome I can not say. Perhaps one of the first requisites is to find some means of overcoming the shamelessness with which individuals otherwise well trained contemplate their own ignorance of mathematics.

The mathematician himself is not disturbed so far as the welfare of his own science is concerned; but it is sometimes a matter of pain to see the general loss which arises from such ignorance and also from the severer strictures of the more pronounced adversaries of mathematics. In no other case, however, have the criticisms been so severe as those meted out to the infinitesimal calculus in the infancy of its development; and never have the fondest hopes of the founders of a science been so far surpassed by its actual achievements as here where the subject has become central in practically every field of pure and applied mathematics.

It will be instructive to examine briefly the criticisms thus met so early by the infinitesimal calculus. Some persons attacked the certainty of its principles, attempting to show that its conclusions were at variance with those obtained by methods previously known and accepted as sound. Some who labored primarily with matters of morality and religion attacked the new departure of thought on general grounds; they repulsed themselves by unwittingly displaying their ignorance of the thing which they criticized. One man, who entrenched himself in masses of calculation, pronounced the procedure of the new calculus unsatisfactory because of the indeterminacy of the form in which certain results appeared; but he afterwards acknowledged his error and admitted that he had been urged forward by malevolent persons—a thing (let us believe) which does not often happen among workers in science. Christiaan Huygens, whose opinion probably carried more weight than that of any other scientific man in his day, believed that the employment of differentials was unnecessary and declared that Leibnitz's second differential was meaningless. But these and many other criticisms never hindered the development of the new calculus, but served rather to aid in clearing off certain excrescences which had nothing to do with its essential characteristics and in helping it to that central place of importance which it holds to-day.

The criticism last mentioned is one which is made so often that it is profitable to dwell longer upon it. So often the mathematician hears: "What is the use of what you are doing?" He knows a thousand answers to this question; and one of the most effective is that which history has given to the criticism of the illustrious Huygens. The recently developed subject of integral equations has sometimes been confronted with the inquiry: Why develop this theory? Will not differential equations serve the purpose? But the mathematician goes calmly ahead with the development of those things which interest him, just as he did formerly; and in the new case he anticipates with confidence the same triumphant justification in the event which has uniformly crowned his labors in the past.

The natural sciences have also been subjected to the same criticism. A narrow view of practical usefulness seems always to dim the vision of those who are unlearned in the progress of scientific discovery and the means which have released into activity the powers of man. They judge from the standards of a daily life in which the prime energy is constantly given to procuring food and shelter or to laying up a store for the future; and it is hard to see the values in a work which does not contribute directly and immediately to such ends. They are not to be judged harshly for this error. It must be admitted that the experience of most of their ancestors leads in the direction of this false judgment on their part. A small number only of the men of each generation see clearly the remoter concerns of mankind; and even they have come to this vision partly from the spur of astonishment at the wonderful values evolving from time to time from abstract considerations.

One of the most remarkable and immediate of these unpredicted values, and at the same time one of the more modern, is afforded by the germ theory of disease. In the middle of the nineteenth century bacteria were known only to a few experts and in a few forms as curiosities sometimes appearing in the field of vision under the microscope; and no one dreamed of their being of importance to man. In fact those who studied them were thought to be wasting useful energy and were subjected to ridicule. But in the midst of wild conjectures and worse logic a nucleus of facts was isolated and some understanding of them began to be realized. In 1860 putrefaction in wounds was ascribed to them, and a few years later their relation to certain diseases began to be known. Then a knowledge of their life-history and action developed rapidly. To-day we understand not only how they are of great concern to us in disease, but also how their action in other ways is of profound importance to our welfare. They are so essential to agriculture, for instance, that our race could not long preserve itself in the present numbers and state upon the earth if the soil were not constantly renewed through the activity of certain of these minute organisms.

Throughout its whole range, from the most abstract considerations in mathematics to the concrete descriptive developments of bacteriology, science at some stage must face the insistent question of its usefulness; and this question it is always answering in ways astonishing even to its ardent supporters.

In the development of physics the infinitesimal calculus has persistently played a leading rôle; its interaction with experimental results has been and is fundamental and necessary to the progress we have witnessed and yet see to-day. From this creation of the mathematicians and the use made of it by the physicists the world has received a good practically immeasurable in its extent. Sometimes we are tempted to assess the advantages due to each of these elements; but one can hardly expect success from such a venture. Logically the mathematics is prior; for it could exist of itself, while the physics probably could not. But psychologically and practically they are so bound up that no separation can be made. Were the mathematics swept away, much of physical theory would likewise have to go; but on the other hand much of the mathematics would never have existed had it not been called into being by the demands of physical science.

This affords us a beautiful and instructive figure of the interaction of one body of truth with another. Neither of these two would exist in their modern state without the spur which it has received from the other. Neither of them should glow with a spirit of boasting. A humble acknowledgment of fundamental indebtedness is more fitting; and it is pleasant to see each characterized by a fervent zeal to return good for good in full measure.

Before turning aside from the relations between natural science and mathematics let us consider briefly a conception or expectation which has arisen in some quarters and having to do with a more fundamental and far-reaching use of mathematics than any yet made. It is connected with the fact that every branch of physics gives rise to an application of mathematics and the consequent feeling that there must be a deep underlying reason for this and a subsequent close relation of phenomena which probably makes them capable of an explanation from a single point of view consistently maintained.

If there is a "hypothetical substructure of the universe, uniform under all the diverse phenomena," it would appear that there must be some means of ascertaining what it is and of giving to it a mathematical expression and body. At any rate the expectation of such a thing has arisen; let us hope that the event will show that the anticipation is well grounded in the nature of things.

It appears that the earliest contributions to just such a development are already in existence; that the now current theoretical accounts of radiation, diffusion, capillary action and molecular behavior in general have just such characteristics as one would expect to find in the early stages of a mathematical theory of the substructure of the universe.

At the opposite pole of knowledge is another stream of thought whose existence or influence is mainly left out of account by scientists just because it is so far removed from that with which they are accustomed to work. But it has profound influence upon life and even affects science in some measure directly though remotely. This is the unsystematic thought which finds expression in literature and art and sometimes in unorganized philosophic speculation. For the most part the domains of systematic and unsystematic thought have little effect the one upon the other; and yet it must be apparent to one who analyzes the fundamental characteristics of our age that these two great arteries of our culture must have somewhere a vital connection. Only rarely does an important truth find its first expression in unsystematic thought and later take up a place in science; and when it does so it is much changed in the process. The poetry of science has not been written and its cultural elements have not found their way into the general thought of mankind.

And yet all science must receive its initial spring from ideas no more definitely organized than the vague intuitions which strive only half successfully for expression in the form of literature or art. Between the two there is, however, this fundamental difference. Even in its early stages a branch of science has to do only with a restricted range of phenomena. It is neccessary to study small sets of closely related matters if we are to get that detailed information on which alone science can rest. We can not obtain definite and precise scientific information about the whole environment at once. We must take it by piecemeal; and so far we have succeeded only where we have isolated the phenomena into distinct and sharply-defined groups. It is quite otherwise in literature, for instance. Here the whole stream of life is contemplated at once, in its fullness and complexity. The results obtained are less definite and are more subject to change from age to age than those of science. Moreover there is less uniformity in the way in which they affect the individuals who consider them. But they have a breadth of reach over the forces of life and the motives of conduct which can be realized only by a single grasp of the whole complex process. Each of these two realms of thought, in its central characteristics, has lessons of value for the other.

Between these two extremes is a middle ground lying undeveloped. One can hardly feel that it is covered by the generalizations of philosophy. To synthesize the results from the separated domains is hardly enough. One desires a means of grasping a more complex portion of reality, vibrant with the pulse of life, and of reducing it to definite order. It appears that no known methods are sufficient for dealing with this problem. Shall we conclude that it is impossible of solution or merely that we have need of a further development before we can expect success with it? Thought as embodied in literature and art took a wonderful form in ancient Greece. There science had merely a beginning and did not acquire sufficient strength to live vigorously through the middle ages. Many centuries were still necessary for a development of its method. Will another period of like extent lead us to other methods equally novel and suitable for the development of this middle territory between literature and our present science?

The logical evolution of science from the vague to the definite is instructive from many points of view. Through untold periods of time for many ages the human mind moved very slowly toward that isolation of phenomena in thought which is essential to the creation of exact science. In action such isolation can not be effected; we must take the whole complex environment at once and do the best we can. This characteristic of the practical life has doubtless been one of the chief factors in delaying the abstractions now so uniformly present in scientific investigation.

In the construction of each particular science we pass through a sequence of stages similar to those which have characterized our general progress in the development of science as a whole. First of all, there is a period in which a given class of phenomena affect us vaguely and we are only half-conscious of their presence as a connected entity in the complex of the environment. They continue to affect us and we have a growing sense of related experiences proceeding from a common source. This arrests attention and excites interest. From being merely passive recipients of impressions we now come to be active in our relation to the phenomena; we observe them directly, and we seek means to affect them so as to ascertain their course or character with more accuracy. We pass to the stage of vague and gross qualitative description of the phenomena. In the course of our study this gives way to a qualitative analysis of the phenomena and a study of their qualitative relations of coexistence. Such is the state to which the biological sciences of the present day have attained. Sociology finds its place even further back in the scale.

Qualitative considerations never become definite enough to meet the ideals of science. It is necessary to go further and find out the quantitative aspects of phenomena and to determine the exact relations of their coexistence and succession; in a word, to render the account mathematical. Once Newton and his followers had succeeded in deducing from a few laws, easily stated and comprehended, the essential facts of astronomical motion as obtained by direct observation, it was impossible that any science should rest comfortably in a state in which qualitative considerations are dominant. The astronomical view was certain to spread into molar and molecular physics and even to find a place in the biological sciences.

The various divisions of physics proper were the first portions of other sciences to approach the ideal conceived on account of the success in astronomy; and chemistry has followed at a distance. As late as 1873 it could be said:

> No theory has as yet been formed in chemistry which, starting from a definite principle, attempts to deduce results of experience as necessary consequences.

Measured by the standards attained by Maxwell and his followers in the theory of electricity, chemistry is still seen to be far short of that standard of excellence which we are able to conceive definitely, notwithstanding the remarkable developments which a generation has witnessed. Perhaps it will not find its true place until we are in possession of more effective means for getting into the atom—not merely the molecule—and studying the properties and connections and positions of its parts.

When a science has reached a certain stage of development, varying greatly with the character of its material, it begins to throw off into the body of society great practical or even esthetic values which could not be realized without it. Astronomy has enabled us to have some conception of the vastness of space and the hugeness of the mass of matter, perhaps infinite in its totality, distributed through this space. Geology has released the imagination to contemplate the enormous periods of time and through its influence on biology has rendered marked service in making possible our conception of the long progress of life on the planet, culminating in man. Mathematics, by exhibiting a body of truth which can live through millenniums without needed corrections and at the same time can grow in magnitude and range and interest, has given the human spirit new ground for believing in itself and for rejoicing in its proved power of consistent thought.

In addition to values of this more ideal sort there are others of a practical nature. Two of the most remarkable are those afforded by chemistry and the theory of electricity. The latter has enabled us to transmit readily and over great distances immense stores of energy, either from a central plant or from some permanent source in nature, and to utilize it for a great variety of purposes. The former has furnished the necessary means for founding certain industries and has contributed essential elements to the maintenance of many others.

But the excellence of science is not altogether in itself or in its fruits. It has interactions with all the fundamentals of life and thought. It moves upon itself, part upon part, and so brings out many values. Of especial import is the effect within itself of the influence exerted by mathematics and natural science, the one upon the other. But it reaches out also beyond its own domain into all the activities of man, both practical and theoretical and speculative. It so moves in his philosophy that thinkers not a few now maintain that the present duty and function of philosophy is to think science, to organize its results and to scrutinize their validity. It so affects daily life in many ways that it can not fail to exert a profound influence upon the unsystematic thought of literature and art as they strive to give expression to the fundamental spirit of life in our age.

From a certain point of view these four main divisions of Thought—mathematics, natural science, philosophy, that unnamed one ruling without definite system in the domain of art and literature—are the stones and brick and mortar from which is builded the culture of the time, into which are wrought the values received from the past, and through which our development shall proceed to the acquisition of new power for further conquest. We break the environment into parts in thought and from these we fashion new objects such as never before existed in the universe—objects both concrete and ideal—and these we put together in ways well-pleasing to ourselves to serve the ends we propose or erect the constructs we conceive.

But this is too mechanical to be the whole truth. The more profound values lie deeper and have their fruition only in the fullness of the character of man. If science did not touch a more profound matter than mere motion or reach to constructs which can not be adequately pictured by material symbols, it would fall far short of the glory of Living Thought. But it does react in a profound way with all our activities. In fact, the elements of all Thought are parts of one body, living and organized, inspired by the breath of the Universe itself and pulsating with the life of truth in its deeper manifestations.

THE RELATION OF PHILOSOPHY AND THE SCIENCES

By Professor G. R. WELLS

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REMARKS on the relation of philosophy and the sciences are, perhaps, best made by one who is quite often supposed to belong to neither of these groups, namely, a psychologist. For as the philosopher usually views a psychologist as one just outside of the sacred pale, so do the scientists often refuse to recognize him as one of themselves. While I would not be understood as calmly accepting the status of a missing link, I do feel that there is some reason for a certain amount of confidence that the psychologist is able to view the two fields of philosophy on the one hand, and science in general, on the other, with a little more understanding than either is able to exercise toward the other. The reason for this is simply that, whether rightly or wrongly, the average psychologist is forced or persuaded to include in his graduate curriculum rather more of philosophy than any other scientist in training.

Etymologically the term philosophy indicates an interest in all knowledge. (So does the term science, for that matter.) To begin with, no doubt, the philosopher was simply the scholar, the learned man. Aristotle was interested in practically everything. And men very much later than Aristotle have taken or have attempted to take, the whole of human experience for their field. One thinks of Herbert Spencer, perhaps of Hegel, and some lesser men in this connection. But except in the cases of the contributions of a very few gigantic men such spreading out of interest has resulted in a thinning of the product so as to make it all but valueless. I have no intention of applying this judgment to the product of philosophy in general. But I do think that the escape from such a situation is often somewhat narrow, and that there is escape at all is due to the fact that philosophy has for many days practically abandoned all attempt to be interested in knowledge in general. No one would dream of going to philosophy to-day for answers to questions of any kind in science, or indeed, to obtain detailed information of any kind, except, perhaps, in the fields of historic folk ethic, or in the history of thought. It is possibly a little hard to realize that the day is not so very long past in which the seeker for knowledge in any field of learning would go, as a matter of course, to the philosopher. In other words the philosopher has comparatively lately ceased to be a treasury of all learning.

It is of passing interest that many of the earliest philosophers were chiefly interested in physics. I refer, of course, to the Greek atomists. Some interest in astronomy was evident at about the same time, and also in physiology of an exceedingly rude type. These interests were treated in their relation to each other, but chiefly in their relation or supposed relation to theology. Specialization was not thought of. But the history of thought shows us that from time to time men whose interest was centered, rather than scattered, split off from the main group, no longer called themselves philosophers and abandoned the philosophical method. The influence of the church was exerted to its utmost to retard this process, being interested as it was not at all in the subject, but only in their real or assumed relation to religion, or rather, to theology. And for this and other reasons, but chiefly for this, it is really late in the history of civilization before physics, chemistry, astronomy, geology and biology were able to constitute themselves as independent lines of human activity, to pursue investigations along lines suggested by their several special interests, and to build up their own bodies of knowledge by using all the ways and means that their initiative and individuality suggested, or at least all that church and government regulation allowed them to use. But such separation always resulted in lasting benefit to all concerned, except possibly certain priest-philosophers, whose individual opinions may have been outraged.

The last of the children of philosophy to leave the parental home is psychology. In fact she is at present just in the act of setting up an establishment of her own, and still remains very much under the influence of her parent. She might be said to be a spoiled child, and to have been too long content to have her affairs managed by her parent. But the signs of the times are indubitably to the effect that psychology *has* set up her own house, and intends to administer it herself.

Now that psychology is leaving or has left the philosophical rooftree I think it may be admitted that to philosophy the house is left somewhat desolate. Perhaps that is the reason why there has been some persistent objection on the part of the parent to the daughter's leaving. But, however that may be, the situation is such that the question becomes pertinent, "What is the proper field of philosophy?" While that question is pertinent my attempting to answer it would be impertinent, and I do not intend to so attempt. I have not the necessary training, whatever that may be, nor is it my place, nor is it my interest to answer it. But answered it must be, by some one, before very long. A smaller question is included in the larger, that of the relation of philosophy to the sciences which it has engendered. It is to that question that my remarks here are directed, but even it I do not expect to answer in full.

To begin with, let me emphasize the fact that the various special sciences which have left the philosophical fold, have not thereby ceased philosophizing. There has been much very significant philosophizing done within the various scientific fields and most of it has been done by men who would be apt to object if they were to be termed philosophers. They would insist that they had not philosophized. But like Monsieur Jourdain and his prose these men have been talking philosophy without knowing it. For instance, in biology the mechanistic vitalistic controversy is in its very nature intensely philosophic, but the worth-while contributions to the discussion are, in an overwhelming majority of cases, made by men not ordinarily listed as philosophers. There are exceptions, some valuable contributions have been made by soi-disant philosophers, but these are true exceptions. I can fancy that many men occupying teaching positions in philosophy have wished that they could take a forceful, not to say creditable, part in this discussion. But, alas, it is necessary if one would enter such a controversy that one possess a good deal of technical knowledge of the facts involved, rather more than is in the possession of many philosophers. In physics or physical chemistry the question as to the nature of the atom or that concerning the nature of ether may be properly referred to as philosophical. But few self-styled philosophers have any remarks whatsoever to make on these subjects. In general, it must be recognized that the division between philosophy and science is not a line between those who speculate, who are interested in abstract questions, and those who are not. The difference is of another order.

As far as the facts in the present situation in the world of thought go, the salient difference is in the breadth of interest. The scientist is one whose interests are strictly limited, the philosopher hates to recognize any limits to his field. The scientist is ambitious to go very deep in a narrow shaft, the philosopher spreads his efforts widely. Each attitude has its perfectly obvious dangers.

These two attitudes are so very different that each of them is almost, if not quite, unintelligible to the other. Few scientists are apt to quite understand just what the philosopher is trying to get at, few philosophers really appreciate what the scientist is trying to do. This mutual misunderstanding of the purpose and value of each other's work is only on the surface, and is only a significant symptom of some much deeper differentiation. For below that matter of the breadth of interest there is a deeper and more vital difference between philosophy and science which I wish to suggest in this paper.

I think there is small doubt but that there are really two very different functions of intelligence, two very different kinds of men engaged in intellectual work.

Men who are interested in knowing are either more interested in discovery, in fact, finding, than they are in systematizing their discoveries, *or* they are more interested in systematizing the facts that have been brought to their attention in whatever way than they are in fact, finding. It is a matter accessible to observation that few men are equally interested in both attitudes. If an ordinary man attempts to do both these kinds of work he will seldom be equally successful in both fields. He may excel in one, and be woefully weak in the other. I hazard the opinion that if a man excel in one of these attitudes, in the vast majority of cases he will be very far from excelling in the other. Only mediocre men, or, on the other hand, only very great men are able to work equally well in both. Of course it should be said in passing that this division of the activities of intellectual men is by no means an original observation on my part. Herbart, among others, has made the same statement, using other terms than those in which I have chosen to describe the two attitudes.

The discovering or fact-finding attitude is precisely what the name indicates, a passion for ascertaining shapes, sizes and incidence of phenomena. It delights to find variations, to uncover new and hitherto unrecognized data. Its method is particular, minute. Its reward is a large or small heap of things discovered. Men with this attitude are the pioneers, not, be it noted, the map-makers. They first make the trails, sometimes in haphazard, if not in accidental fashion. They are men whose preeminent virtue it is to *see* well, and in some fashion or other to record what they see.

The systematizing attitude is interested less in minute and detailed facts than in their arrangements, their relations, their patterns. To find, not a new fact, but a new law, is their delight. It is related of Clerk Maxwell, I think, that in boyhood he would say with regard to some natural phenomenon brought to his notice, "What I want is the particular go of it." Clerk Maxwell was probably of more significance as an organizer of facts than as a fact finder.

The economical thing is surely to recognize the difference between the two functions, and not to demand fact-finding from the systematizers, nor theorizing of great acuteness from the average discoverer. And inasmuch as both of these functions are of necessity essential to all sciences, some arrangement should be made, or recognized if already made, giving equal opportunities to the two approaches to truth. Furthermore, equal credit or reward should be apportioned to painstaking work in either field.

It takes a good deal of courage, perhaps amounting to foolhardiness, to mention names in this connection. I am not possessed of sufficient knowledge of science in general to dream of making even approximately complete lists of men in these two fields, but there are certain cases so outstanding that the mention of their names will illustrate, if it does not prove, my point.

A particularly interesting and complete example of the two attitudes is found in the labors of Tycho Brahe and John Kepler. These two great men worked practically as a team. The one, Brahe, was above all an experimenter, an observer. The other, Kepler, not only was not notable as an observer, but in fact was possessed of vision so far below normal acuteness that he was almost useless for astronomical work from the experimental end. But his contributions to astronomical knowledge were the most significant made by any man up to the time of Newton, with the possible exception of Galileo, and have been exceeded by few men of any time. To this work of Kepler's, however, Brahe made absolutely necessary contributions. Without Brahe Kepler could not have worked. Without Kepler Brahe's work would have verged on the valueless. Brahe's theories were almost grotesque, and Kepler could not have observed with great acuteness or accuracy if he had tried. The two made a perfect team, each being the other's complement to a degree seldom equalled in the history of science.

Newton's work was entirely theoretic. He did practically no fact-finding. He was a systematizer par excellence. His mighty contributions to knowledge were all in the realm of theory. He required absolutely that other men furnish him with facts. Men whose names we hardly know, and no doubt men of whom we have never heard, furnished the material from which he fashioned his laws. And without the results of the labor of these obscure or nameless workers Newton himself would have remained obscure. When as a marvellous boy he worked out the mathematical calculations which were to establish the theory of gravitation, his calculations concerning the curvature of the moon's orbit seemed to work out incorrectly. There was evidently some serious error of misapprehension. He knew it was not in his mathematics. All his work was based upon the accepted belief of the time that a degree on the earth's surface measured sixty miles. It is to me a curious thing, an amazing fact, that under these circumstances he made no attempt as far as I know to substantiate this measurement. Instead he laid his figures aside for sixteen years. Then a lesser man than Newton experimentally determined that this estimate of the length of the degree was incorrect by nearly ten miles. Whereupon Newton returned to the long-neglected and almost forgotten calculations, and found that in the light of this new experimental fact they were completely adequate. And so he gave the world the theory of gravity and inverse squares. As a fact-finder Newton was not eminent, as an arranger and explainer of facts he was unapproachable.

Clerk Maxwell, Willard Gibbs, Arrhenius! Do these names suggest to you facts or theories? The latter only. I think none of these men did any discovering. But they practised wizardry in the realm of law.

There are equally notable examples of men who have discovered much, but have theorized little, or at least only in unsatisfactory terms. Such men are a little harder than the others to name, because history has valued them less than the others, and many of them, no doubt, have been forgotten.

I have already mentioned Brahe, a shining example. In the realm of biology we find Mendel. Perhaps his work is not entirely characteristic, but at least it is true that he hardly recognized the overwhelming value of his observations. Rowland, the physicist, was essentially a fact-finder, Edison and Marconi come in the same group. Add to these a hundred thousand obscure laborers in the laboratory and in nature, essential men doing absolutely essential work if science is to progress.

A few names are great in both lines, Darwin, Helmholtz, Cuvier, Bovari.

These instances, all too few and briefly put, serve perhaps to illustrate the point I wish to make. Not all men are interested in nor *fit for* experimental work, discovery, fact-finding. Not all men are capable of theorizing in permanent terms. Very few men can do both. The theorizers are the philosophers. But why do they not, or can they not, also observe? The reason is perfectly obvious. Philosophy is not a subject. It is a method. The philosopher is not fundamentally different from the scientist because his interests are broader, but because his methods are different. The two methods require very different mental attitudes and aptitudes. I think it can be put in other words by saying that there is no such thing as philosophy *per se*. Philosophy must be philosophy "of" something, of physics, of chemistry, of biology, of religion, of behavior, and so on. And before the philosopher can work there must be something to work upon, material to be provided by the fact-finder, who must go ahead and pile up these facts to be arranged later by other hands than his.

For this reason it is that the contributions of the earlier philosophers is of little value in the light of present-day science. They had so little to work with in the way of definitely ascertained knowledge that the finest intellects and the best will in the world could have accomplished nothing. How could they observe and state the laws underlying the movements of phenomena when they did not know the phenomena? But the more or less complete failure to recognize this elementary fact has wasted much time and energy.

The place of philosophy as a college department it is presumptious for me to discuss. But is it prophesying for me to suggest that each department of science will, in time, do its own instructing in the philosophy of its own subject? Courses may be included in the offerings of each university scientific department on the philosophy of biology, of physics, of chemistry, of psychology. For the attitude of psychology toward philosophy is not different from that of any other of the sciences, except perhaps that the amount of definitely determined facts makes a comparatively small heap, and that there are some peculiarly involved philosophical problems to be handled.[1]

Beyond philosophizing in the various fields there may be a possibility of some superman relating these various philosophies

[1] My friend, Dr. Dunlap, of Johns Hopkins, has suggested to me that something of the same sort may come in time to be true of history. We may come to hold that history in general is too large, or too vague a subject for one group of men to handle. And so we may some day have in each department courses in history, history of physics, of chemistry, of biology, of government, of economics, of art and literature. That would leave untreated only the history of war. And perhaps some day that may be left to the department of archeology to handle.

to each other. For all facts of experience may, after all, be one fact, in some sense which it is impossible, even absurd to dream of now. But the man who can see and state these universal relations must do so on the basis of his knowledge of the detailed technic of all sciences. It will require a super Newton, a super Helmholtz, a greater Aristotle. But for him who can do it that will be the great task.

These remarks are not to the effect that philosophy has no relation to or place in science; quite the contrary. The value of philosophy to science depends upon the degree to which philosophy is in science, rather than above it. Science uses, or should use, philosophy as a tool, a method, for specific and limited purposes. Philosophy is the handmaid and not the mistress of the sciences. Failure to recognize the ancillary function of philosophy, attempts to enthrone it, have caused some harm to science, but much more harm to philosophy itself. To this error we may truthfully attribute the modern and regrettable belittling of philosophy.

WHY DOES OUR PUBLIC FAIL TO SUPPORT RESEARCH?

By Professor T. D. A. COCKERELL

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WE have in our town a useful and patriotic citizen, sometimes suspected of having Irish blood in his veins, who formerly was a member of the State Senate. Many years ago, the president of the State University appealed to the legislature for a small fund in aid of research. Our senator, in the presence of the president and the students, humorously explained on a later occasion why the appeal failed. The president had made his speech to the committee on appropriations, and was listened to with due courtesy. But when he went out, one of the legislators spoke up: "Say, what *is* research?" Another replied, "D——d if *I* know," and a third proposed "Let's lay it upon the table." There it has rested ever since.

We all had our laugh, in which the president himself good-naturedly joined; but the query of the old farmer-legislator, "Say, what *is* research?" has remained as unanswered by the general public as it was in that committee-meeting. The public believes in education, and will support it up to a certain point. It has a good deal of regard for the sports, and is sure that football is one of the major functions of a university. But it is d——d if it really understands research, and unfortunately is likely enough to be damned eventually by that lack of understanding. Research and teaching are the twin functions of the university, but we are told that teaching is the prime necessity of the day, and research can wait. Actually, it does not wait. We do what we can, as best we can, and for the rest depend for our knowledge on the activities of other states and nations. Intellectual parasitism is so easy, in the sciences or the arts. The world does move, so why not ride upon its back?

Yet the other extreme, of complete intellectual independence, would be much worse. We must of necessity be part of the great body of science, but it should be a living part, not some shell-like external secretion. No state, no city, can afford to be left out of this movement; the eventual penalty is inability to even profit by the work of others.

it should be a matter of personal and social pride. It is of incalculable advantage to any state to belong to the Union, but in the present condition of public opinion there are some disadvantages. If Colorado were a nation, she would as a matter of course have strong institutions for scientific research, and would publish the results of investigations made by her citizens. Being only a state, she is cheerfully willing to see these activities center in other parts of the country, and has little idea of squarely shouldering her own burden. One can easily imagine, and can even find in various countries, excessive local pride leading to absurd results. Our extreme modesty (is that the word?) is not wholly bad. Yet the problem of the states is something like the problem which confronts many of our educated young women. They might fly, could they only believe themselves to possess the wings. Long ages in the apterous condition have produced an inhibition scarcely to be overcome. Yet it will be overcome, in both cases, in the fullness of time.

It is unreasonable to expect the demand for intellectual achievement to develop abundantly among the masses. Reforms start with individuals rather than with multitudes. If we are really to progress, the universities and the men in them must show the way. They must press their cause with so much zeal and sincerity as to convince their students, and their students' students. The torch of Agassiz is growing dim, but it has burned brightly through more than one generation. One looks into the faces of nearly two thousand young men and women at assembly, and thinks, if they all *cared* enough, what might they not do? If they cared for their country and their fellows enough to work and think, year after year, how to make America what America once meant to be!

They don't care like that, and we don't. The stream will not rise higher than its source. If we could do no better, this argument would be wasted ink. But as William James used to say, we practically all of us have unrealized reserves of force. We found that out in the war, and should not forget it in peace. The power is there, both material and spiritual, and only the stimulus is lacking.

I have little respect for the methods of the revivalist, and should regard with grave suspicion sudden conversions to the religion of science. One has to grow into it, and up to it. Yet it is absolutely certain that such growth will only occur in adequate quantity under favorable conditions. It is nonsense to say that the scientific man must be a genius, and as such will defy the very gods to win a footing. He is usually a man (or woman) of rather ordinary ability, somewhat above the average, who will work when suitably fed, housed and clothed. He wishes to be understood and appreciated, and get due credit for what he does. He does not demand riches, but he is jealous of his rights, and has a sense of justice. All of which is to say that he is a normal American citizen, and desires to be taken as such. He appreciates the indescribable romance of science, the triumphs of discovery, the dawn of new ideas; but all this is part of life, and may come to the merchant, the artist or the farmer, if in somewhat different form. Scientific research is not a thing isolated; it is part of the necessary work of the world, and when once that is understood, it will take its place along with our other normal activities.

We of the university do not appreciate this. We hear it said, and repeat the saying, that one who has the true research spirit will make discoveries, if he has to take the night hours and holidays to do it. It is true enough, but suppose we reverse the picture for a moment. Suppose we imagine a university given over to research, but with students as at present. Professors are paid to do research, and called to account for it, but they teach when they can, or feel inclined. Oh well, if a man has the true teaching spirit he will gather a following, and so the youth will be instructed! The history of the world proves that; Jesus Christ, the greatest of all teachers, got no pay but the cross. Admit all this, and it remains evident to the least intelligent that the education of a democracy can not be left to the occasional influences of spirits too insistent to be crushed. Indebted as we are to the inspired, most of our knowledge and training must come through much more prosaic channels.

No one doubts this, in regard to education. Once there used to be a doubt, but it has long since passed away. We have an educational program, which actually suffers from excess of system. We have gone to one extreme with regard to education, to the other with regard to research. We have no research program. The administration receives no reports on research, and asks no questions regarding it.[1] No one on the campus can tell accurately what the research activities of the university are. Is it therefore remarkable that the public does not know, and legislators possibly think of research as a scheme to give lazy professors more time to loaf? It would be horrible to have

[1] Plans for reform in these matters are under consideration in the University of Colorado.

research administered by a stiff and unintelligent machine, but is that any reason why it should be left to shift for itself unaided? The fault, of course, is not peculiar to any one institution or locality. In some degree it even represents an exaggerated virtue, that of recognition of the independence of the investigator. It is not easy to reach optimum conditions or practices, in teaching or research, but without a certain efficiency in both our democracy can not be adequately maintained.

With a definite program, sufficient means for publication, and dignified arrangements for publicity, I believe there would be no great difficulty in obtaining the support of a majority of the citizens. When it becomes apparent that science can create wealth, banish disease, and illumine the mind, it will be regarded as the indispensable friend of mankind. Scientific writings will themselves become a prime factor in the education of citizens, not simply on the campus, but all over the country and at all times. But it is not sufficient to preach the virtues of science in general. People must be shown in detail, in a thousand ways suited to their particular needs and interests. Hence the propaganda, if we may so designate it, must be in the hands of the scientific men themselves. They alone know the facts, and can speak with conviction.

The problem is not one of finding support for a certain number of research workers. If there were no opportunities for research, the majority of potential investigators would turn to something else, and probably attain greater material prosperity. The problem is, to create and maintain a service, without which civilization will stagnate, and eventually decay. Those who have faith in science do not believe such an outcome possible, but look forward to continually accelerated progress, and the removal of many of the greatest evils which distress mankind.

SCIENCE AND THE STATE

By Dr. WILLIAM SALANT

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THE revolution in sentiment which is being wrought by the war is perhaps most strikingly illustrated by the public recognition of the value of scientific investigation. The idea is fast gaining ground that science is indispensable for the preservation of modern society and may be considered one of the most profitable lessons taught by the war.

According to a declaration of the British Labor Party the advancement of science is placed in the forefront of its political program. The necessity of scientific development is emphasized by the incorporation into its political platform, of recommendations for the deliberate organization of research. This attitude of a group of radical labor leaders toward scientific activity might well be regarded as highly significant of the trend of thought at the present day. For never before has any political party embodied in its declaration of principles the advancement of science as national policy.

Evidence that the progress of science is no longer to be left to chance is also furnished by the announcement of the British Ministry of reconstruction after the war.

Its plans which were published about two years ago indicate that definite form has been given to the recognition that science is the corner stone not only of modern warfare but also of the future society which is to follow the establishment of peace. Judging from the number and the organization of the various boards and committees the object is to stimulate scientific research along different lines on an unprecedented scale. The scheme of this highly important body includes among other items in its program the appointment of two research boards on scientific and industrial investigations, five standing committees, seven research committees, four inquiry committees and three provisional organization committees. Official recognition of scientific investigation was not confined, however, to the British Isles. The colonies have also realized the necessity of scientific investigation as was shown by the establishment of a similar organization in Canada at the head of which is the well-known physiologist Professor A. B. McCallum. It is pertinent to inquire therefore what our federal government is doing in the way of promoting scientific investigation especially of the type which will be needed after the war. As it is necessary to look into the future and make provision for the solution of various problems which will arise when peace is established a review of the scientific activities of the government and the conditions of scientific work may, therefore, be helpful in preparing for the greater task which is to come, for the analysis of conditions may suggest changes that will lead to necessary improvements in an important branch of the service which has within recent years assumed large proportions. It is not generally realized that the federal government has for years employed a number of agencies for carrying on scientific work of every description. This activity of the federal government is very significant, as it indicates recognition by the American public of the need of scientific work for the solution of practical problems. It shows the realization by the average citizen that science is a necessity and is entitled to support by the government. This has for years been strongly reflected in the liberal appropriations made for this purpose by Congress.

According to Van Hise the appropriation in most federal organizations varied in 1911 from $100,000 to $1,000,000. The total amount per annum available for investigation and supplies was more than ten times as much as any single university or institution in the country spent for this purpose. This did not include the appropriation for the Department of Agriculture, which in 1911 spent twenty million dollars, a large part of which went for scientific and extension work. This appropriation for the Department of Agriculture has since been greatly augmented. For a number of years this department has been receiving enormous sums from the treasury for scientific work. Every science was represented. Every branch of chemistry, human and veterinary medicine, botany, zoology, agriculture and economics were included in its official statement. The estimated cost of the various scientific undertakings for 1917 was over four million dollars, nearly all of which was to be devoted to the various sciences as related to agriculture in all its ramifications. Examination of the program of work published by Department of Agriculture shows that the solution of a very large number of problems have been attempted and still more are contemplated. It may be pointed out that the annual appropriations for research in the various bureaus for 1917 varied between $60,000 and $1,645,640. Moreover the appropriations do not include large amounts spent for routine testing which has to be carried out in connection with the regulatory work of the department. Very often problems suggest themselves when routine tests are made and demand solution. Appropriations of very considerable size are also made annually for statistical work and for the study of various economic problems. The sum of four million dollars mentioned above does not represent, therefore, the entire amount spent in investigation and research in that department. To this sum must also be added the upkeep of buildings and libraries, and the money invested in the equipment of laboratories. Large appropriations for scientific work in other departments have been made by Congress during the last few years immediately preceding our entry into the war. The Bureau of Standards, the Bureau of Mines, the Bureau of Fisheries, the Naval Observatory, the Geological Survey and other government bureaus have been granted large sums of money for scientific work. It is difficult to quote in figures the exact amounts devoted to research in each case as they very seldom appear in the official records. But the Geological Survey received in 1916 $40,000 for physical and chemical research. Since it is well known to scientific men that research forms part of the activity of these organizations it is reasonable to infer that the total amount of money spent annually for scientific investigation in all the departments of the government must be considerable, though, by no means, so large as that devoted to similar purposes by the Department of Agriculture. The achievement of scientific results is, therefore, a matter of much concern to the public. Their practical importance can not be overestimated since the various undertakings were intended to meet the daily needs of our life. To what extent agriculture, sanitation, preventive medicine and other public activities will be benefited, only those familiar with the problems in the numerous laboratories can fully realize. The possibilities inherent in the opportunities offered for making contributions of great value to the stock of useful knowledge are practically unlimited. It is realized, however, by those conversant with the actual state of affairs that advantage is not taken of the opportunities to the extent that it should, as science neither pure nor applied derived the benefit which might be expected.

It has indeed been pointed out several years ago by Van Hise that the advancement of science in its broader aspects is contributed to by only a few of the scientific bureaus at Washington. The Geological Survey, he remarked, was for a number of years the center of the world for the "advancement of the science of geology but it is not contributing in any large degree to the advancement of science at present." Such a statement coming as it does from an eminent geologist who had for years been associated with Geological Survey is very significant, as it shows a state of affairs which should not exist. Unfortunately his statement still applies to some bureaus at present. The wide recognition by the public that scientific investigation is a necessity and that the application of the results of research are essential to the very existence of a great nation make it apparent that the conditions surrounding scientific investigation and research in the federal government should not be a matter of indifference to the public and should form an object of especial interest to all scientific workers in the country. This claim upon their attention applies with even greater force to men of science at this hour, for after our entry into the war the number of scientific projects undertaken by the different government agencies markedly increased. Besides, there is every indication that scientific activity, carried on under the auspices of the federal government, is destined to assume much larger proportions during the period of reconstruction than before the war. The number of scientific workers in the employ of the government promises, therefore, to become permanently large and the problems they may be called upon to solve are likely to be more serious and more numerous in the future than they have been in the past. The treatment of scientific workers, particularly those who have demonstrated their ability to carry on and to direct investigation deserves special attention, for upon them largely depend the objects to be achieved. Proper treatment at the hands of bureau chiefs and heads of departments is essential to success in research. The necessity of improving the conditions of scientific work should be recognized, therefore, and the much-needed reforms should be introduced without delay. Initiative should be permitted and encouraged. There is nothing in our form of government to prevent it. The numerous, petty and annoying regulations should be abolished, as they defeat the very object for which laboratories are established. The establishment of an agency to carry into effect a certain project carries with it by implication authority to employ the methods necessary for the achievement of results. It would, indeed, be considered unreasonable to expect results without the necessary physical equipment employed in the experimental sciences. The need of instruments and apparatus is readily admitted and is usually provided. This applies with even greater force to the intangible conditions in the absence of which scientific work is either wholly impossible or is at best extremely difficult. The need of a free hand to achieve results when any serious project is undertaken is fully recognized and it is, of course, to be assumed that scientific work in the government is and should be made a serious matter. The condition of the heads of laboratories is especially worthy of attention, for upon them rests the responsibility for carrying out the various scientific projects and it is they who are accountable for the results. Practically all of them are near or past middle age and the possibilities of their being called to fill similar positions elsewhere is very remote. If the tenure of office is so uncertain, as shown by a recent case in the Bureau of Chemistry, that their services may be terminated at any moment and on the slightest pretext, directors of laboratories and their associates are wholly at the mercy of their superior officers. Such conditions are absolutely incompatible with the proper performance of duty and the achievement of scientific results and besides compromise the dignity and self-respect of scientific men. Except under very unusual circumstances, as when the head of a laboratory, or a man in charge of a project is not wholly dependent upon his position for a livelihood, the discharge of his official and professional obligations with any degree of satisfaction to himself and in obedience to the interests of his real employer—the public—becomes almost an impossibility. It is not necessary to dwell upon the influence which such conditions will exert upon the morale of the individual concerned and, therefore, upon his scientific work. The result is necessarily and inevitably disastrous. A policy whereby scientific workers of every grade and description would be shown consideration is urgently needed in every bureau and demands immediate attention. Recognition of merit by promoting the industrious and efficient as well as the recognition that a scientific worker, in whatever capacity employed, has rights that a superior officer is bound to respect, under pain of disgrace and dismissal, would keep intact the organization of useful and productive laboratories. This could be accomplished without added expense and would be beneficial to the public service directly by increasing the volume of scientific work and improving its quality, and indirectly by affording thorough scientific experience to young men and women. Increase of appropriations are hardly necessary to carry into action such a policy, but what is more important is the inauguration of a policy looking forward to the transformation of every unit in every bureau into a harmonious effective organization. But to carry out such a policy men of marked ability and devotion to the cause of science and to the highest interests of the public are needed. The important fact can not be overlooked that one of the lessons of the early days of the present war was that no nation can afford to neglect its scientific workers or to allow its research agencies to be disorganized and wasted. The most patriotic service that can be rendered is to be ready with our laboratories fully equipped and working at their highest possible efficiency. The reconstruction of our national industries to meet the needs of the world's food supplies and the world's industries, as well as to meet the competition of other nations will demand that American men of science be ready as they have never been before to match their research skill against that of the whole world, which necessitates that our government should lead in every branch of scientific work. Its organization of science should be a model to the country and to the whole world, as otherwise we may be outstripped by other nations in industry and in commerce. While private philanthropy has done much for science in this country it should not be forgotten that the government with its unlimited resources can do vastly more than can ever be accomplished by the wealthiest and most generous individuals. Scientific research is a very expensive undertaking. The cost of some of the constituent laboratories of the Rockefeller Institute and of the Carnegie Institution is between forty and fifty thousand dollars a year. The multiplication of such laboratories will undoubtedly become a necessity in the near future. Is it not too much to leave the development of science to chance and to the generous impulses of men of wealth? Besides it is hardly conceivable that private philanthropy will be equal to the occasion in the future for the scientific undertakings promise to be so vast that the government alone will be equal to the task. The movement in this direction is, however, not new for this country. Public opinion will undoubtedly approve of more thorough organization of science by the government and of more liberal support for it in the future than in the past. There is every reason to expect that we can accomplish even more in this direction than the other nations, since our resources are practically unlimited.

INERTIA[1]

By SIR OLIVER J. LODGE

WE are each of us flying through space at nineteen miles a second, probably much more. Nothing is propelling us; we continue to move by our own inertia, simply because there is nothing to stop us. Motion is a fundamental property of matter. No piece of matter is at rest in the ether, the chances are infinite against any piece having the particular velocity zero; every bit is moving steadily at some given speed, unless acted on by unbalanced force. Then it is accelerated—changed either in speed or direction, or both.

As a matter of fact we, like other bodies on the earth, are acted on by two slight unbalanced forces—one which makes us revolve round the earth once a day, like a satellite, the other which makes us revolve round the sun once a year, like a planet or asteroid. Our annual revolution is not because we are attached to the earth; we are not attached, but revolve as independent bodies, and would revolve in just the same time and way if the earth were suddenly obliterated: only then we should find the diurnal revolution transmuted into a twenty-four hour rotation round our own centers of gravity, and the excentricity of our annual orbit very slightly changed. In any case there is no propelling force, only a residual radial force producing curvature of path.

A railway train, or a ship moving steadily, is likewise subject to no resultant force. Propulsion and resistance balance. The whole power of an engine, after the start, is spent in overcoming friction. The motion continues solely by inertia. Any steadily moving body is an example of the first law of motion. You need not try to think of a body under no force at all; you cannot think of such a body on the earth, but you can think of one under no resultant force, *i.e.* under balanced forces. Such a body moves by reason of its inertia alone. It is in equilibrium: it is not at rest.

But we have no sense of straightforward locomotion, and not the slightest clue to either the magnitude or direction of our motion through space. We can ascertain approximately

[1] Amplified from a lecture on "Ether and Matter," given before the Royal Institution of Great Britain, on February 28, 1919.

how the sun is moving with reference to our system or cosmos of stars, but we do not know at what rate that system is itself moving. For all we know it may be moving very fast: hundreds of miles per second.

We have a sense of acceleration however; we experience it in a lift as it begins to descend; and if the sensation is repeated often enough, as on a rough sea, the result is unpleasant. We have also a sense of rotation; we can tell when our vehicle—say a Tube train—turns a corner in the dark. Most animals appear to have a sense of rotation, apparently located in the ear. But we have no sense of direct translation; and we have so far failed to devise any instrumental means for detecting our motion through the ether of space.

The failure is not for lack of trying. Many experiments have been tried, but there is always some compensating effect; so we get no answer to the question—at what rate and in what direction are we moving? The best known experiment is that of Michelson and Morley, the result of which seems to assert that the ether clings to the earth, or that the earth is not moving through any kind of substance. But Fitzeau's classical experiment showed that a transparent body carried with it none of the internal ether of space; and experiments made by myself at Liverpool in the nineties of last century show that a rapidly moving opaque body carries no external ether with it, that there is no perceptible viscous drag or cling between matter and ether, and accordingly demonstrates that stagnation or absence of relative ether drift past the earth is not a reasonable explanation of Michelson's negative result.

The two experiments together, in fact, ought to be taken as establishing the reality of the most interesting of all the compensating effects yet discovered, viz. the FitzGerald-Lorentz contraction of all matter in motion, which the electrical theory of cohesion renders so extremely probable. It only amounts to a 3-inch shrinkage in the whole diameter of the earth in the direction of motion; but it is enough. This slight contraction or change of shape in moving bodies I regard as the definite and interesting compensating effect in this case. Incidentally, moreover, it establishes the electrical, *i.e.* the chemical, nature of cohesion. For given that cohesion is a residual chemical affinity—due to the outstanding attraction of molecules composed of neutral groups of equal opposite electric charges, brought so near together that the attraction between molecules is no longer averaged to zero—then, on orthodox Maxwellian electric theory, a diminution of this force due to lateral motion is inevitable. And the resulting lateral expansion or longitudinal contraction, or both, is of the right order of magnitude. So this acts as a previously quite unsuspected compensating effect, which exactly neutralizes the drift effect otherwise to be anticipated. Thus, by superposition of two positive consequences of drift, the Michelson experiment, like every other yet made, declines to indicate that there is any drift at all.

Hence, after many such negative results, it seems to become hopeless to enquire experimentally as to our motion through ether. Unless indeed gravitation were exempt from the otherwise universal compensation. In that case the electrical theory of matter applied to the motion of planets might yield a residual result. But my recent enquiry into this problem has suggested that gravitation too is in the conspiracy, and in that case there is some ground for the contention of the extreme Relativists, not only that we do not know our motion—with which everyone agrees—but that we never shall know it: and, in fact, that motion of matter through ether is a phrase without meaning.

I hope we shall not too readily shut the door on further attempts in this direction; and as a conservative physicist I may be allowed to lament the extraordinary complexity introduced into physics and into natural philosophy by the principle of relativity, as so remarkably and powerfully developed by the mathematical genius of Einstein, with complication even of our fundamental ideas of space and time. The complications do not commend themselves to all of us, and I for one should be glad to return to the pristine simplicity of Newtonian dynamics, modified of course by the electrical theory of matter; admitting the FitzGerald-Lorentz contraction, and admitting also the variation of effective inertia with speed. These things do not destroy, but supplement, Newtonian dynamics. They generalize it in a legitimate and intelligible manner. Such complications as these are clearly in accordance with truth and are to be welcomed; but the complicated theory of gravitation created this century by Einstein and developed by his successors, and the consequent overhauling of space and time relations, do not at present commend themselves to me, nor I think to others of what I suppose must be called the older school.

Meanwhile the full-blown theory has the courage of its conviction and has predicted a definite result, viz. the deflexion of a ray of light by the sun's limb, equal to 1.75 seconds of arc. The prediction is going to be tested during the solar eclipse of

May 29, 1919, between Brazil and the Gulf of Guinea. Let the issue be clearly understood. If a star-ray grazing the sun is deflected ¾ second it will mean only that light has weight, that the wave-front not only simulates the properties of matter by carrying momentum—as we know it does from the investigations of Nichols and Hull, Poynting and Barlow, and others—but that it is even subject to gravity. For this would be the angle between the asymptotes of a cometary orbit when the comet is moving with the speed of light and passing close to the sun. But the principle of relativity—through the refractive or converging influence of a strong divergent gravitational field—demands a greater deflexion than this, more than twice as great. So there are three alternate deflexions before us, to be settled by observation:

1.75 sec.; 0.75 sec.; and zero.

Let us hope that the result of this or of some other eclipse-opportunity may be definite enough to discriminate clearly and quantitatively between these three alternative values; any one of which should be equally welcome to any lover of truth.

If the first answer is given decisively, it will be a conspicuous triumph for the theory of relativity, and will for a time be hailed as a death-blow to the ether. I claim beforehand that such a contention is illegitimate, that the reality of the ether of space depends on other things, and that the establishment of the principle of relativity leaves it as real as before; though truly it becomes even less accessible, less amenable to experiment, than we might have hoped. Nevertheless the ether is needed for any clear conception of potential energy, for any explanation of elasticity, for any physical idea of the forces which unite and hold together the discrete particles of matter whether by gravitation or cohesion or electric or magnetic attraction, as well as for any reasonable understanding of what is meant by the velocity of light. Let us try to realize the position beforehand; for we shall be handicapped in the progress of our knowledge of the relation between matter and ether until these fundamental things are settled, and until everyone agrees that the ether has a real existence. I want people generally to admit that the ether is itself stationary as regards locomotion, and that it is the seat of all potential energy; and further, at least as a surmise, that it is the medium out of which matter is probably made, and in which matter is perpetually moving by reason of its fundamental property called inertia—a property the full explanation of which must, I expect, ultimately be relegated to and considered as a property derived from the ether itself.

I call this lecture "Ether and Matter," but I might equally well have called it "Inertia," for that is the main theme with which I have to deal—at least in this first part.

Is there anything else, besides matter, which possesses or seems to possess inertia! Faraday discovered that an electric current had a property which bore some analogy to inertia, a property clearly depending on its magnetic field. Every current, even a convection current, is necessarily surrounded by lines of magnetic force, and when the magnetic field is intense the current behaves as if it had considerable inertia. Faraday at first called the effect "the extra current." Maxwell called it "self-induction." The latter is the better name.

To show it I start a current in a circuit containing a stout ring of laterally subdivided iron round which the current-conveying wire is wound, and I put in circuit an instrument which only responds when the current has risen to nearly its full strength. A current usually rises, what is called, instantaneously, but here there is a very noticeable delay between pressing down the key and the response of the instrument. The lag shown is only a second or two, but with care I can adjust it till it is a quarter of a minute. Such delay or lag in establishing a current would be fatal to electric telegraphy. In practice the delay is reduced to a minimum, by using its early values, and the actual response is exceedingly quick. Still, the law of rise of current is quite definite, there is no exception, it is only a question of degree; and the law is the same as that appropriate to the pulling of a barge on a canal. A barge gets up speed slowly, at a rate depending on its mass or inertia, and it ultimately attains a steady speed when the resistance balances the pull.

That is exactly the case of a steady current obeying Ohm's law, the E.M.F. is balanced by the resistance, the propelling force is zero, and the current flows by what we may call its own inertia—its own momentum.

To stop the current you must either increase the resistance or suspend the propelling force. If you interpose an obstacle suddenly, the motion stops with violence—a collision in the case of a train or barge, a flash in the case of electric current. This is what Faraday called "the extra current at break," and if you are holding the wires in your hand when the current is suddenly broken in a circuit of large self-induction you may get a nasty shock.

If you could abolish electric resistance a current would go on for ever without propelling force.

An amazing experiment has been made by Kamerlingh Onnes at Leiden, who first cooled a metal ring down to within four degrees of absolute zero by means of liquid helium, and then started a current through it by a momentary magnetic impulse. Instead of stopping in a minute fraction of a second, as usual, the current went on and on, not for seconds but for days. In four days it had fallen to half strength, and there were traces of it a week later. A most suggestive experiment as to the nature of metallic conduction, as well as a demonstration of the fly-wheel-like momentum of an electric current!

This electromagnetic analogue to mechanical momentum or inertia is explicable (or supposed to be explicable) in terms of the magnetic field surrounding the current, *i.e.*, really (as I think) in terms of a property of the ether of space. It exactly simulates inertia; but is it an imitation or is it the same thing? Can it be said that an electric charge possesses inertia in its own right, and retains it always, as matter does, whether it be moving or whether it be stationary?

The question was brilliantly answered by your Professor of Natural Philosophy, Sir J. J. Thomson, so long ago as 1881. He calculated the inertia or quasi "mass" of an electric charge e, on a sphere of radius a, and showed that it was $m=\frac{2\mu e^2}{3a}$.

The μ need not be attended to now, though it is really the most important of all—being a great etherial constant of utterly unknown value[2]—but for our present purpose the μ merely signifies that the e must be measured in electromagnetic not electrostatic measure, when the formula is interpreted numerically with $\mu=1$.

At the date 1881 this expression for true electric inertia, though an interesting result, seemed too absurdly small to have any practical significance. Take a sphere like a football, 20 centimeters or 8 inches in diameter; charge it till it is ready to give more than an inch spark, say up to 60,000 volts; then calculate the inertia or equivalent mass corresponding to the charge. If I have done the arithmetic right it comes out one-third of a millionth of a millionth of a milligramme (3×10^{-16}). Absurdly small! Yes, but not zero. And whenever a quantity

[2] I have guessed that it is a density of 10^{12} grammes per c.c. $\div$ 4π. See "The Ether of Space," Appendix 2; also the *Phil. Mag.* for April, 1907.

is not nothing, there is no telling what importance may not have to be attached to it sooner or later. Nothing real can be so small as to be really negligible in the long run as knowledge progresses. Something at present unforeseen may bring it into prominence. So it has turned out in this case. The infinitesimal result of nearly forty years ago to-day dominates the horizon. It was in some sort the dawn of a new era in physics.

Consider it further. Clearly the inertia depends not on the charge only, but on its concentration. The radius of the sphere occurs in the denominator of the expression. The same charge on a sphere 2 centimeters in diameter would have ten times the inertia; on a sphere as small as an atom the inertia would be a hundred million times bigger still. But then even that is small; moreover an atom could scarcely be expected to hold such a charge. Nevertheless, allowing only a reasonable potential, it might seem that atomic inertia could be sensibly increased by an electric charge. But no, even on a sphere as small as an atom the concentration turns out insufficient; the effect is still excessively minute. Yet as electric inertia at given potential depends on linear dimensions, while material inertia depends on those dimensions cubed, there must be a size when the two are equal, *i.e.* when one might account for the other.

Write the charge in terms of electrostatic potential V

$$e = KaV$$

then

$$m = \frac{2KaV^2}{3c^2}$$

where c is $1/\sqrt{(\mu K)}$, the velocity of light.

Put this expression for m equal to $\frac{4}{3}\pi a^3\rho$, the ordinary mass.

Then the potential at which the two will be equal is

$$V_1 = ac\sqrt{\left(\frac{2\pi\rho}{K}\right)}$$

which, for density of water and for sphere 10^{-13} centimeters radius, is two volts; quite a reasonable electrolytic value, such as is to be expected among atoms.

The moral of this elementary but not very satisfactory argument is that not for bodies of atomic size, but for something 100,000 times smaller in linear dimensions, is it possible to explain inertia electromagnetically. But, forty or even twenty years ago, one would have said—there are no bodies of this size; nothing can be smaller than an atom! The strange thing is that, as nearly everyone knows now, bodies of this size have been discovered. They were isolated by J. J. Thomson in 1899, having been gradually led up to by Crookes's and many other experiments on cathode rays; and they are shown to be an apparently invisible unit or atom of electricity whose inertia is wholly electric.

The proof of this last statement I can only briefly indicate. It is established by the effect of speed on electric inertia. If an electric charge is moving with something approaching the velocity of light, its inertia increases without limit; and the formula given about 1889 by Heaviside, Thomson, and others, for electric inertia as a function of speed, is, in its very simplest form,

$$m = \frac{2\mu e^2}{3a}\left(1 + \frac{v^2}{2c^2} + \text{higher powers}\right)$$

The velocity of light squared occurs in the denominator, so, before we can observe the increase, enormous speeds are necessary. A cannon-ball, or even the earth in its orbit, is hopelessly slow; and we know no artificial means of getting up such a speed as this last, viz. about 19 miles a second. But fortunately radium does spontaneously what we cannot do, it expels electrons with something less, but not very much less, than the speed of light; and Kauffmann's measure of the mass of these projectiles, thus flying at prodigious velocities, confirms the theory, and removes any doubt as to the reality of purely and wholly electric inertia, for electrons.

Furthermore it was found that the very same electrons can be split off or detached from any or every kind of atom, that there is only one kind of negative electron; and though at first there appeared to be many kinds of positively charged particles, the evidence is tending to the discovery of a single kind of positive electron likewise; so it is natural to suppose that electrons are an essential ingredient in matter. And since they possess inertia, even those which are clearly disembodied electric charges, it becomes possible to surmise that in some sense, or in a certain grouping, they constitute the atom, that they confer upon it the inertia with which we are familiar and that in fact electric inertia is the only inertia that exists.

Electric inertia began as the simulacrum of material inertia, it has shown itself the very same thing, and it seems likely to end by displacing every other kind of inertia altogether.

This is the electrical theory of matter.

Assuming this theory for the present as a working hypothesis, we may say that material inertia is explained electromagnetically, *i.e.* is explained in terms of the magnetic field which necessarily surrounds and accompanies every charge in motion; since a charge in motion constitutes a current. For on this view a material body is but an aggregate of such charges grouped according to some definite pattern, positive and negative charges interlaced or somehow intertwined, and so far apart in proportion to their size that they do not interfere with each other or cancel each other, nor apparently overlap or encroach on each other's field, to any measurable extent. Is this possible? It is. For comparing the size of an electron with the size of an atom we perceive that they are relatively of the same order as the size of a planet and the size of a solar system. So it becomes possible to think of an atom as a sort of solar system, with a positive nucleus or sun surrounded by negative electrons revolving in regular orbits round it.

On this view, or indeed in any form of the electrical theory of matter, the atom of matter consists mainly of empty space; in other words, it is excessively porous; just as the solar system is mainly empty space and may be spoken of as excessively porous; the actual material lumps being almost infinitesimal in proportion to the total bulk. A rapid projectile or a ray of light passing through the solar system would be unlikely to hit anything, the chances would be strongly against a collision. So also, if a point be thrown through an atom, the chance of its hitting anything is about 1 in 10,000. It might pass through 10,000 atoms before striking. This experiment has been tried, by C. T. R. Wilson and others, and that is roughly speaking the result. Sooner or later a radium projectile meets with an obstacle and is stopped, but it traverses a good number of atoms on the average; it traverses quite a perceptible distance even in a dense solid, before it strikes a nucleus.

Matter accordingly seems to me—to us I may say, for in this most physicists are I think agreed—a gossamer or milky-way structure, an impalpable accident in the substantial ether. Here a speck and there a speck, but, for the great bulk of it, empty space!

"Impalpable" is not the right word, for matter is essentially palpable. It is because it appeals so directly to our senses that we attend to it so vividly. It forces itself on our attention, while the ether eludes us. And why? Clearly because our bodies are composed—our sense organs are composed—of this very matter. On the material side we are part of, and thoroughly at home in, the material universe. Whereas the ether is elusive; we know nothing of it directly; and though our eyes are instruments for receiving etherial tremors excited by agitated electrons, we only know that fact—or half know it—by rather recondite inference. Light really tells us nothing about its own nature, but only about the superficial aspect of that gross and palpable matter which has interfered with and scattered it before it enters our eye.

Nevertheless the atoms of this solid-seeming flesh and matter as we know it, when analyzed into constituents, are turning out to be composed each of a definite grouping of ultra-minute particles, the positive and negative electrons, which themselves hardly occupy any space (save as soldiers occupy a country), and which appear to be of two kinds only—the ultimate indivisible units of positive and negative electricity.

THE MECHANISM OF EVOLUTION[1]

IN THE LIGHT OF HEREDITY AND DEVELOPMENT

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V. The Cellular Basis of Ontogeny and Phylogeny

B. MECHANISM OF HEREDITY

2. *Share of Cytoplasm in Heredity*

THE evidences outlined in the preceding section demonstrate that the chromosomes contain the factors or genes of Mendelian inheritance, and it has been assumed by many investigators that the cytoplasm of the germ cells serves only as environment or food for the chromosomes and has nothing to do with heredity. Nevertheless there are certain characters of the embryo and adult that are derived directly from the cytoplasm of the egg and since these characters come from the mother and not from the father this may be called "maternal inheritance."

(*a*) *Differentiation of Cytoplasm of Germ Cells.*—The cytoplasm of both male and female sex cells is differentiated. A spermatozoon is perhaps as highly differentiated as any tissue cell; but these differentiations which have been built up during the late stages of spermatogenesis and which serve to bring the spermatozoon into union with the egg, disappear after that union either by the tail of the spermatozoon being left outside of the egg or by its disintegration or de-differentiation after it has entered. At the same time the egg ceases to form yolk while that which has been stored in the egg is gradually used up in the nourishment of the embryo. Consequently since these particular differentiations of the germ cells disappear after the union of egg and sperm it has generally been supposed that all cytoplasmic differentiations of these cells are wiped out at this time, and that the first differentiations of the new individual begin after fertilization in a wholly undifferentiated cytoplasm. However there is positive evidence that this is not the case and that many differentiations of the cytoplasm of the unfertilized egg persist and play an important part in embryonic differentiation (Fig. 22).

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 18, 1917.

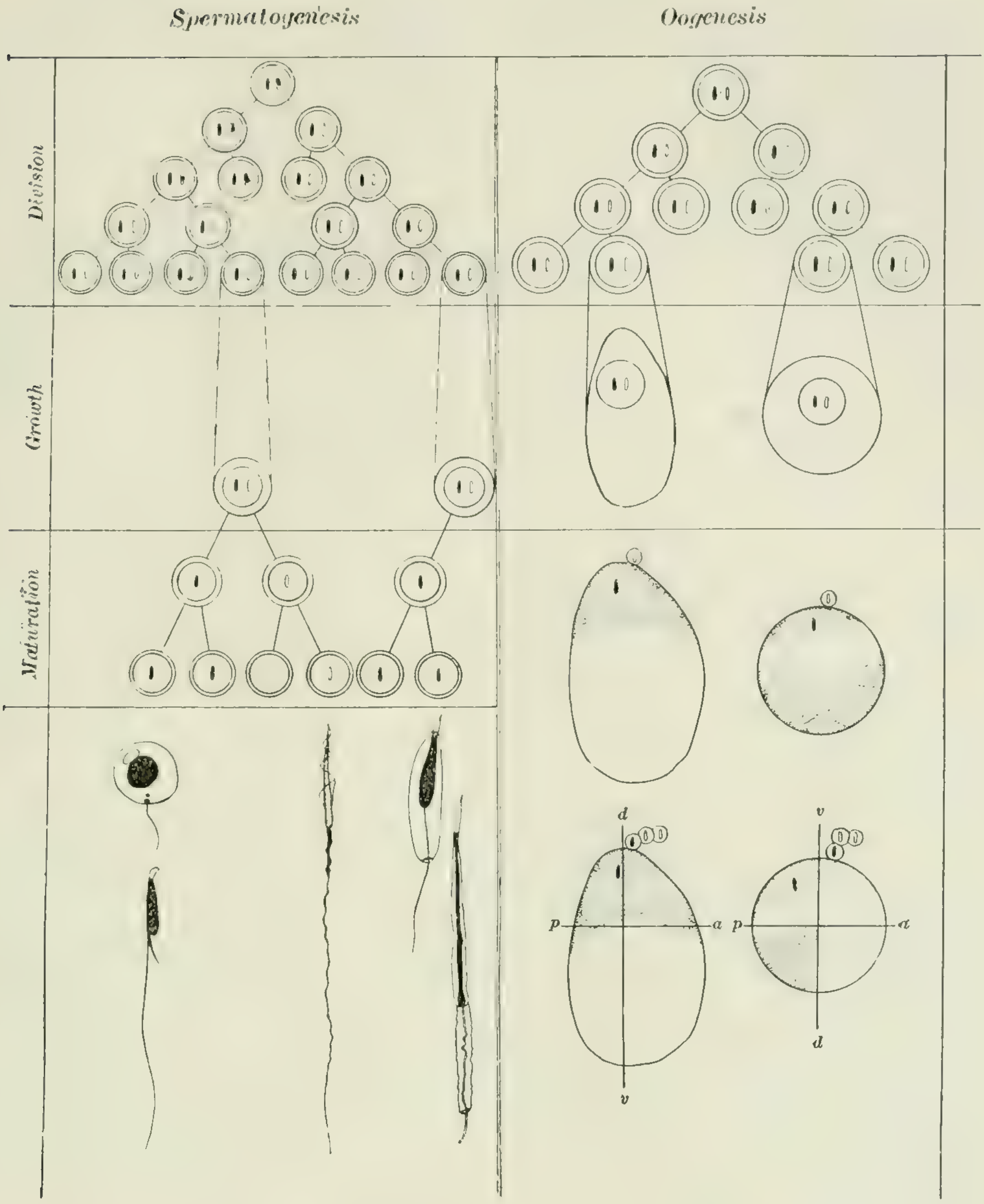

FIG. 22. DIAGRAM OF SPERMATOGENESIS AND OOGENESIS, showing Division, Growth and Maturation Periods and Final Stages of Spermatozoa and Ova. Two chromsomes, one from the father the other from the mother, are shown in each cell before maturation, only one after the reduction division. Three kinds of highly differentiated spermatozoa are shown and two kinds of ova. The differentiations of the spermatozoa are lost after they enter the egg, the polarity and symmetry of the egg persist and determine the orientations of development.

(b) *Egg Differentiations which persist in Embryo and Adult.* (1) *Polarity.*—The polarity of the egg invariably determines the polarity of the embryo and adult. In all animals the chief axis of the egg becomes the chief axis of the gastrula, and this becomes the chief axis of the adult in sponges and cœlenterates (protaxonia), or, as in all other metazoa (heteraxonia), this axis is bent on itself by the greater growth of the gastrula on its posterior side so that the chief axis of the adult is a modification of the gastrular axis. In either case the polarity of the unfertilized egg determines the localization of developmental processes and ultimately the polarity of the developed animal.

(2) *Symmetry.*—In most animals the egg is spherical in shape and appears to be radially symmetrical, nevertheless observation and experiment show that such eggs are sometimes bilateral, as is probably the case in *Amphioxus*, ascidians, fishes and frogs. In the case of the frog's egg it was long believed that the plane of bilateral symmetry was determined wholly and exclusively by the path of the spermatozoon within the egg; more recently it has been shown by Brachet (1911) that primary bilateral symmetry is present before fertilization, though after fertilization the plane of symmetry may be shifted into the path of the spermatozoon. It is probable that all bilateral animals come from eggs which show a similar primary bilaterality and that this differentiation precedes fertilization. In cephalopods and some insects all the axes and poles of the developed animal are already recognizable in the egg before fertilization. Symmetry, therefore, as well as polarity, is derived from the egg and not from the sperm.

(3) *Inverse Symmetry* (*Asymmetry*).—In many animals the right and left sides of the body are not completely alike, and this is especially true of internal organs. This asymmetry is especially well developed in gasteropods in which certain organs of one side of the body are entirely lacking; some species or individuals have these asymmetrical organs on one side, others on the other side, and correspondingly the snail shell coils in a clock-wise direction in one case, an anti-clock-wise direction in the other. It was discovered by Crampton (1894) and Kofoid (1894) that in sinistral species the direction of certain cleavages of the egg (viz., the third to the sixth) was the reverse of the corresponding cleavages in dextral species and Conklin (1903) showed that the first and second cleavages also were in opposite directions in dextral and sinistral snails, and that these reversals of cleavage could be followed cell by cell to the reversal of symmetry in the larva. Consequently the inverse symmetry of these snails may be traced back through the later and earlier cleavage stages to the unsegmented egg itself which is inversely symmetrical in sinistral as compared with dextral forms.

(4) *Types of Egg Organization.*—The polar differentiation of an egg is manifested particularly in the localization of different kinds of materials in different parts of the egg. These materials may be inert pigment or yolk, but their localization

by the activity of the cytoplasm indicates a definite pattern of organization in the cytoplasm. This pattern of egg cytoplasm differs greatly in certain phyla, there being a cœlenterate type, an echinoderm type, a turbellarian-annelid-mollusk type, and a chordate type. The type of egg organization foreshadows the type of adult organization; in ascidians for instance distinct cytoplasmic substances are found in the egg in the same relative positions and proportions as the ectoderm, endoderm, mesoderm, notochord and nervous system of the embryo (Fig. 5, p. 495).

That the fundamental pattern of egg cytoplasm is not influenced by the spermatozoon is proved by the following facts:

(*a*) It exists before fertilization, or it appears so soon after that it could not have been caused by the sperm. (*b*) In heterogeneous fertilization the pattern of the egg is not changed by the foreign sperm. (*c*) Natural or artificial parthenogenesis demonstrates that this pattern exists in the absence of fertilization.

These as well as other facts such as the correspondence between the size of the egg and the size of the embryo (Morgan); the transmission of chromatophores and peculiarities of leaf coloration by the female and not by the male germ-cell in plants (Baur, Shull); the transmission in the egg cytoplasm of fat stains, chemical substances, immunizing bodies and possibly parasites, prove that,

> at the time of fertilization the hereditary potencies of the two germ cells are not equal, all the early development, including the polarity, symmetry, type of cleavage, and the relative positions and proportions of future organs being foreshadowed in the cytoplasm of the egg cell, while only the differentiations of later development are influenced by the sperm. In short, the egg cytoplasm fixes the general type of development and the sperm and egg nuclei control only later differentiations (Conklin, 1908, 1915).

Ontogeny begins with the differentiation of the egg in the ovary and not at the moment of fertilization; at the latter time some of the most general and fundamental differentiations have already occurred. Indeed the cytoplasm of the egg is the more or less differentiated body of the embryo.

(*c*) *Is Inheritance through the Egg Cytoplasm Non-Mendelian?*—Whenever a character is transmitted as such through the egg cytoplasm and not as factors in the chromosomes of egg and sperm it is not inherited in Mendelian fashion. Thus if chromatophores are transmitted from generation to generation in the cytoplasm of the egg and are at no time influenced by the sperm, their mode of inheritance is non-Mendelian. If the polarity, symmetry and pattern of the egg do not arise during oogenesis, but are carried over unchanged from generation to generation they are also non-Mendelian characters. With regard to the polarity of the egg, it is not certain whether it is transmitted in this manner or not; but its symmetry and pattern of organization are probably developed anew in each generation. However, Kunkel (1903) and Lang (1904) found that inverse symmetry is not inherited in Mendelian fashion and that it is doubtful whether it is inherited at all.

Most of the cytoplasmic differentiations of the egg and sperm arise during the genesis of those cells, just as in the case of tissue cells. Nerve cells and muscle cells differentiate under the influence of maternal and paternal chromosomes, and undoubtedly the same is true of most of the differentiations of egg and sperm; but while some of these egg differentiations persist in the new individual those of the sperm do not. Consequently, in each generation the egg contributes more than the sperm to ontogeny. There is cytoplasmic inheritance through the female only, but some of these cytoplasmic characters may be of biparental origin. If these characters are determined by genes in the chromosomes of cells from which the egg develops this is Mendelian inheritance or "preinheritance" though somewhat complicated by the fact that every ontogeny has its beginnings in the preceding generation, that is in the oogenesis, preceding fertilization; if they are not determined in this way but are carried from generation to generation in the cytoplasm the inheritance is non-Mendelian. The fact that certain differential factors must be located outside the chromosomes will be considered further in the section on the "Mechanism of Development."

3. *Specificity of the Germ Cells*

One of the greatest advances in biological knowledge during the past century is found in the increasing recognition that vital units are specific and that the larger units of organization are themselves composed of many minor units having their own individuality and specificity. All cells, or "vesicles" as they were called by Wolff (1759), were at first supposed to be alike, and protoplasm was regarded as a uniform substance in all organisms; it was, in the language of Dujardin (1841), "Substance glutineuse, parfaitement homogène, élastique, contractile, diaphane. On n'y distingue absolument ancune trace d'organization, ni fibres, ni membranes, ni apparence de cellulositié." When this view was no longer tenable this simplicity and homogeneity were ascribed to germinal layers, embryonic cells and germ cells. Even within recent years cleavage cells were said by Driesch (1893) to be all alike, "like balls in a pile," and differentiations were said to appear only late in development as the result of environmental conditions. So great was the influence of the doctrine of Epigenesis! Finally when this was disproved, the various constituents of cells such as cytoplasm, nuclei, chromatin, chromosomes, etc., were supposed to be alike in all cells.

Now, on the other hand, we consider that there are as many different kinds of protoplasm as there are different kinds of cells,—that one chromosome differs from another and that even chromosomes and genes are individually distinct and peculiar. Perhaps the most general and important discovery as to the mechanism of heredity is that germ cells are as specific as developed organisms, that "the egg of a frog differs from the egg of a hen as much as a frog differs from a hen"—indeed that just as every sexually reproduced animal or plant differs more or less from every other one so every germ cell differs more or less from every other germ cell.

Considering the vast numbers of germ cells which exist, their minute size and the difficulty of directly determining differences between them this statement may well challenge criticism and call for proof. And yet there is no gainsaying the fact that hereditary differences are due to germinal differences, and although no man can actually see the differences between the germ cells of different races or sometimes even of different species or genera, the results of development clearly demonstrate that such distinctions exist. In this case as in so many others physiological indicators are more delicate than morphological ones.

We have physiological proof that different chromosomes of the same cell differ in hereditary value and that different germ cells from the same individual frequently differ in hereditary constitution. In the separation of bivalent chromosomes at the reduction division each chromosome may go into either of the two daughter cells and the number of different combinations of chromosomes which may occur in the gametes is $(2)^n$, in which n is the number of bivalent chromosomes. Thus if there are 24 bivalent chromosomes, as in man, the possible permutations of these in the germ cells is 2^{24} or 16,777,216 and the possible number of different *combinations* of maternal and paternal chromosomes in the fertilized egg is this number squared or approximately three hundred thousand billions, though the actual number of *genotypes* is only 3^{24} or about thirty thousand billions, assuming that every chromosome differs hereditarily from every other one. Consequently it is not surprising that successive children of the same parents are rarely if ever alike, since their chromosomal constitution is rarely if ever the same.

But the case for the specificity of germ cells is even stronger than this for there is reason to believe that particular chromosomes are not always composed of the same chromomeres (see p. 289) and the possible permutations of the many chromomeres of each chromosome furnishes an almost infinite number of combinations of units which are still visible with the microscope. Finally when we consider the possible combinations of still smaller units such as genes it is probable that every separate oosperm and every individual which develops from it is absolutely unique.

This conception of the specificity of gametes and zygotes sets the whole problem of the mechanism of heredity in a clear light. Unique individuals come from unique germ cells. Hereditary resemblances and differences in adult organisms are correlated with resemblances and differences in the germ cells from which they came.

C. Mechanism of Development

Development is progressive and coordinated differentiation by which the egg becomes the embryo and ultimately the adult organism. It is concerned with the manner in which the egg cell gives rise to different kinds of embryonic and tissue cells and with the way in which the latter form various cell products such as muscle and nerve fibrils, cartilage and bone. Development is also concerned with the coordination and integration of these differentiations so that an orderly arrangement of parts results. The mechanism of development, like the mechanism of heredity, is a cellular problem and it can be discovered only by the study of the cellular differentiations and integrations of development. But development, or the *transformation* of germinal units into developed characters, is a much more complex process than heredity, or the *transmission* of germinal units from one generation to the next, and at present relatively little is known as to the precise mechanism of such developmental transformations.

1. *Stability of Chromosomes in Development*

One of the most striking facts in ontogeny is that amid all the remarkable changes and differentiations which are taking place in cells their chromosomes remain almost entirely unchanged.

(*a*) *In Egg and Sperm.*—This is true of all kinds of cells but it is nowhere more striking than in the egg and sperm. These cells are notably unlike each other; the spermatozoon is one of the smallest of all cells, the egg is one of the largest, and correspondingly the entire nucleus of the spermatozoon is often smaller than a single chromosome of the egg; virtually all of the cytoplasm of the sperm is converted into a complicated locomotor apparatus whereas the cytoplasm of the egg is abundant, relatively undifferentiated and contains much yolk. It is certainly no exaggeration to say that the sperm and egg differ as much as muscle and nerve cells or as connective tissue and gland cells. And yet in spite of this great difference between the two germ cells their chromosomes are so much alike after they have united that it is usually impossible to distinguish them. The extreme differentiation of the spermatozoon has not in any way changed its chromosomes for they issue from it exactly as they went into it, the same in number, shape and even in genetic constitution in spite of the fact that they have been compressed into one of the smallest of all nuclei in one of the most highly differentiated of all cells.

(*b*) *In Tissue Cells.*—The chromosomes of tissue cells are, in many cases, precisely like those of the oosperm. The differentiations which the cell body has undergone do not usually modify the chromosomes. This is especially true of embryonic cells where mitoses are more abundant and more easily studied than in fully developed tissue cells. In Orthoptera, according to McClung, not only the number of all the chromosomes but even the shape of each particular chromosome is constant for all cells of a given individual, though they may differ slightly in different individuals of the same species. Hoy found that the numbers and shapes of chromosomes in embryonic muscle, nerve, gut and connective tissue cells of certain insects were the same as in the fertilized egg.

On the other hand, Miss Holt found that the number of chromosomes in the alimentary tract of larval mosquitoes might vary from 6 to 72 but always in multiples of 3, the haploid number in this species. She concludes therefore that these variations in number are due either to a double splitting of each chromosome in certain mitoses or more probably to the failure of the cell to divide after the chromosomes have divided. The latter is a phenomenon which not infrequently occurs in cells subjected to experimental conditions. Hance found in the pig that the somatic chromosomes of many cells are more numerous than the diploid number but he has proved that this is due to fragmentation of chromosomes, the fragments when added together merely equalling in length the original chromosome. Such fragmentation of chromosomes in somatic cells was first observed by Boveri in the case of *Ascaris megalocephola* var. *univalens* (Fig. 23). Here the diploid number of

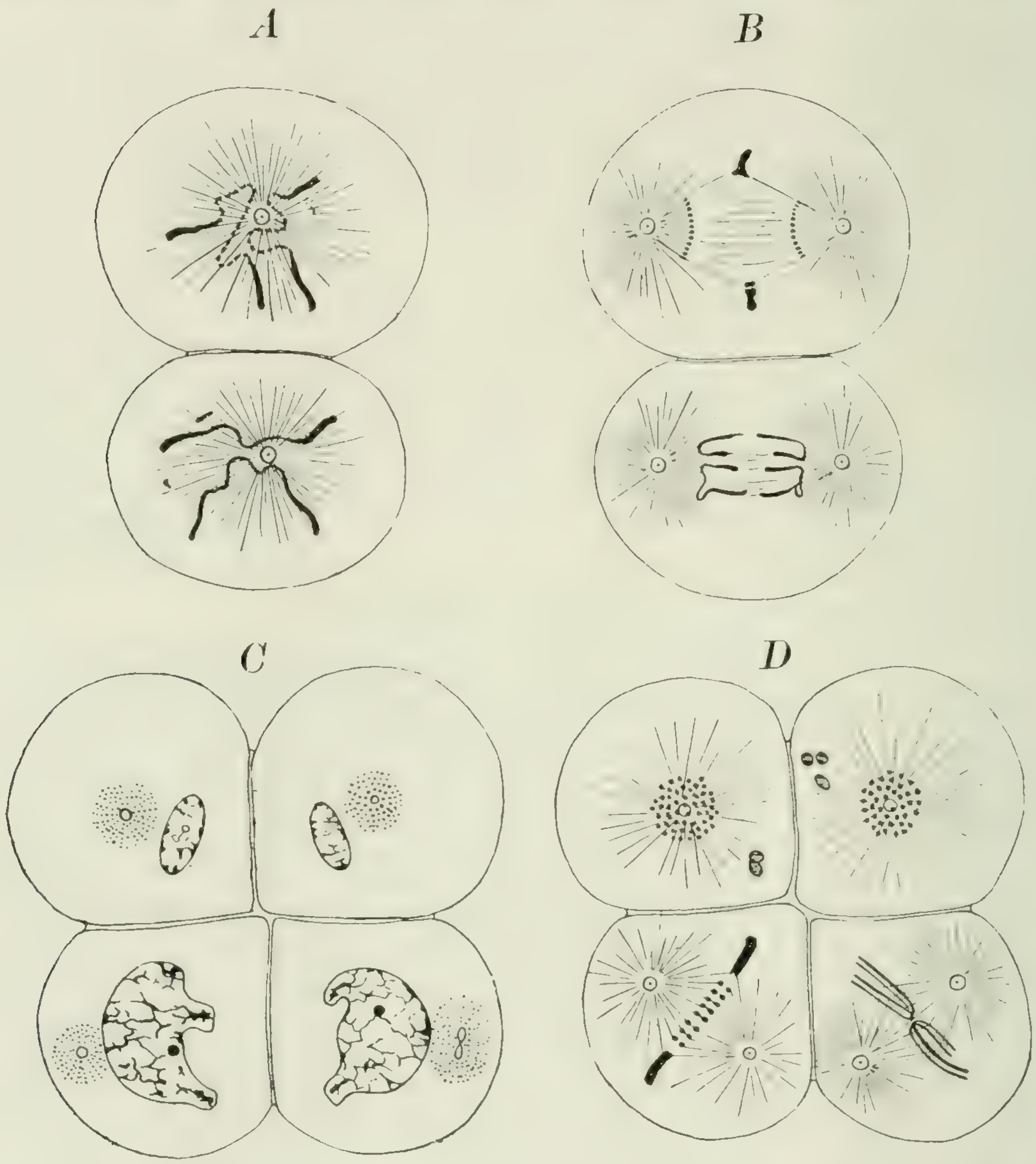

FIG. 23. DIFFERENTIATION OF CHROMOSOMES OF SOMATIC CELLS IN *Ascaris megalocephala*, var. *univalens*. *A* and *B*, Second cleavage mitosis showing the chromosomes entire in the lower cells (germ track); in the upper (somatic) cells their ends are thrown off and the remainder breaks up into many small chromosomes. *C*, 4-cells, the upper two (somatic cells) containing small nuclei derived from the small chromosomes. *D*, Third nuclear division, showing the somatic differentiation of the chromosomes in all the cells except the lower right one, which alone is in the germ track and will give rise to sex cells. (After Boveri.)

chromosomes is 2 but in somatic cells more than 30 small chromosomes (or chromomeres) are present, the total volume of which is even less than that of the 2 original chromosomes since the ends of these chromosomes are cast off and dissolved in the cytoplasm (Fig. 23, *C*, *D*). Boveri has proved by experiments that whether chromosomes fragment or not depends upon whether they lie in a particular field of differentiated cytoplasm and consequently that this is due to the influence of cytoplasm on the chromosomes, and not the reverse.

In conclusion, the chromosomes of tissue cells, as well as those of germ cells, are usually unmodified by the differentiations of the cell body. In other cases these chromosomes may be fragmented or possibly otherwise modified by the differentiations of the cell body. But there is no evidence that the differentiations of these chromosomes are primary and that they cause the differentiations of the cell body as Weismann assumed.

2. *Differentiation of Cytoplasm in Development*

The cytoplasm is the chief, perhaps in some cases the only, seat of differentiation in the developing organism. Practically all the differentiations of cells, tissues, organs and persons are differentiations which arise (1) by transformations of cytoplasm (autoplasmatic differentiation) or (2) as secretion products of cytoplasm (apoplasmatic differentiation).

a. The Structure of Cytoplasm in General.—All students of the cell now agree that protoplasm is composed of a more fluid and a more solid portion, though there is much difference of opinion as to the form of each of these and their relations to each other, as is shown by the various theories of the "structure of protoplasm." The more fluid part is often called enchylemma or cytolymph, the more solid part spongioplasm or kinoplasm; the latter forms some sort of a framework, in the form of fibers, or a net-like or a foam-like structure while the former fills the interstices which are left. Recent experiments on cells and protoplasm indicate that these two portions may vary in consistency at different phases of cell activity, such variations being perhaps in the nature of reversible sols and gels.

But whatever the relation may be between these portions of protoplasm, experiments in which cells are subjected to strong centrifugal force indicate that the framework of the cell is a viscid, elastic, contractile gel which is more rigid at certain phases of the cell cycle than at others, depending probably upon its water content, and that within this gel are included water, oil, yolk, pigments, granules and other products of differentiation.

In addition to this general framework of spongioplasm there is present in many cells, especially at the time of division, a special structure, the mitotic figure or amphiaster, consisting probably of an elastic, contractile gel which takes the form of a spindle with star-shaped radiations at its two poles. This amphiaster is undoubtedly an apparatus for the division of the nucleus and cell body, but we do not know exactly how it functions, though it probably brings about intra-cellular movements, together with segregations and localizations of different cell substances.

b. Formation of Different Substances in Cytoplasm.—In the course of development different substances are formed in different parts of cells or in different cells. The exact manner in which these substances are formed is a matter of great interest in connection with the mechanism of differentiation and development. Unfortunately our knowledge upon this point is very incomplete. The general evidence seems to favor the view that the nucleus cooperates in the formation of the various differentiation products which appear in the cytoplasm; in general these substances are not formed when the nucleus is absent though once differentiation of cytoplasmic substances has begun it may go on for a time in the absence of the nucleus. The manner in which the nucleus cooperates in differentiation has been variously interpreted by different authors. Weismann assumed that in mitosis there was a differential distribution of the nuclear inheritance factors to the different cells and that in this way the differentiations of development were to be explained. The evidence is all against this view as Boveri and others have shown. In the first place the splitting of chromosomes is never differential and the mitotic apparatus is unsuited to a differential separation of daughter chromosomes. Only in the separation of whole chromosomes which had previously united in pairs, as in the maturation divisions, is such a differential separation possible. In the second place the experiments of Driesch and O. Hertwig on compressed frog's eggs and of Conklin on Ascidian eggs proves that nuclear divisions are not differential, but that cytoplasmic divisions often are. Finally the differentiation of the somatic chromosomes of *Ascaris* (Fig. 23) is due to the fact that they lie in a field of peculiar cytoplasm as Boveri has shown; consequently such chromosomal differentiations are the result of cytoplasmic differentiations and not their cause.

(1) *"Intracellular Pangenesis."*—Under this name deVries (1889) proposed a hypothesis of the way in which the nucleus controls differentiation which nearly meets present requirements and fits present knowledge. He suggested that particles which he called "pangenes" and which he regarded as enzymatic in character escape from the nucleus into the cell body

where they form the entire living protoplasm. Most of the nuclear pangenes are inactive but they may be activated by age or outer circumstances. Every nucleus contains a full set of pangenes and there is no differential division of them in mitosis. The pangenes which escape from the nucleus must be transported to different parts of the cell and segregated at the right places and this transportation and localization is brought about by the streaming of the protoplasm.

In its main features this hypothesis is acceptable to-day. However deVries's conception that "every inherited character has its particular kind of pangene," has suffered the same fate as the more recent view that "determinants," "determiners" or "inheritance factors" are the germinal representatives of developed characters. These are not the germs of developed characters any more than oxygen and hydrogen are the germs of water; on the other hand they are only specific causes which, acting in conjunction with other causes, produce specific results.

Furthermore it is not now believed that genes or pangenes maintain their identity in the cytoplasm and that the entire cytoplasm is composed of them. It is not even known that genes escape *as such* from the nucleus into the cytoplasm but it is known that there is an escape of nuclear substances into the cytoplasm and that as a result of syntheses of these with portions of the cytoplasm new substances are formed which were not present before.

(2) *Escape of Nuclear Substances into Cell-body*

(*a*) *At Mitosis.*—Every cytologist is familiar with the fact that various nuclear substances escape into the cell-body. One of the most striking instances of this occurs during mitosis when the nuclear membrane is dissolved and its contents are set free into the cell. In some cases the entire volume of nuclear materials which are thus set free has been estimated to be five-hundred times as great as the volume of the chromosomes which give rise to the daughter nuclei. Among the nuclear materials which thus escape are nuclear sap, linin, nucleoli and oxychromatin. The last is probably derived from the chromosomes and it takes part in the formation of the "sphere substance" which surrounds the centrosomes. This sphere substance is differentially distributed to different cleavage cells as for example in the case of Crepidula (Conklin, 1902), and it probably cooperates in the differentiations of these cells.

The immediate results of the escape of nuclear materials into the cytoplasm are both varied and striking. At once there is greatly increased oxidation with the formation of carbonic acid, and the cell which was before relatively stable and resistant becomes unstable and peculiarly liable to injury.

Another result is the rapid formation of astral rays and spheres around the centrosomes; indeed very much of the cell cytoplasm may be transformed into these structures following the escape of nuclear material during mitosis.

Another notable result of this escape of nuclear material is found in the movements which are set up in the cell and which lead to the separation of daughter chromosomes, the orientation of spindles, the localization of different cytoplasmic materials and finally the division of the cell-body. All of these movements, which may be collectively known as karyokinesis and cytokinesis, start with the escape of nuclear material into the cytoplasm.

(*b*) *Chromidia.*—R. Hertwig and his associates maintain that chromatin may escape through the nuclear membrane into the cell-body during resting stages. Such escaped chromatin forms chromatic granules which they call "chromidia" and which they believe take part in the differentiation of various intracellular structures, such as skeletal, muscle- and nerve-fibrils, secretion granules, pigment and the Nissl-bodies of nerve cells. However it is not certain that chromidia are derived from escaped chromatin.

(*c*) *Mitochondria.*—Other observers, particularly Meves and Duesberg, have described granules, rods or threads in the cytoplasm which are known by the general name of "mitochondria" and which appear to take part in the differentiations of specific structures. Meves and Duesberg regard these as purely cytoplasmic bodies which have the power of growth and division. Hertwig and his school hold that they are derived from chromidia, and therefore in the beginning from chromatin; more probably they are new formations caused by the action of chromatin on cytoplasm.

(3) *Cytoplasmic Differentiation*

One of the simplest cases of differentiation is found in the formation of secretion products within cells, such as yolk, oil, and zymogen granules. These usually appear as minute granules or droplets which then grow in size until they more or less completely fill the cell. Whether they are products of destructive or of constructive metabolism is not altogether clear; probably in some cases they are the former, in others the latter.

Yolk and zymogen begin to form in the vicinity of the nucleus and in many cases out of a granular mass which is either chromidia, mitochondria or the granular substance surrounding the centrosomes and known as "sphere-substance." In some cases, perhaps in all, the granular body known as a "yolk nucleus" is sphere-substance derived from the interaction of nucleus and cytoplasm; according to the Hertwig school zymogen granules are always derived from chromidia and pigment usually comes from the same source.

Intra-cellular fibrils, such as skeletal, muscle- and nerve-fibrillæ, are also derived from chromidia, according to Goldschmidt, and hence are formed in large part by substances derived from the nucleus. On the other hand, Meves and Duesberg maintain that such intra-cellular differentiations are derived from mitochondria which are purely cytoplasmic in origin. The more probable view is that mitochondria are formed by the interaction of nucleus and cytoplasm, and that all other cellular differentiations are formed in the same way; and if all these cytoplasmic differentiations are produced by the action of chromatin on cytoplasm, the chromatin is only one factor in their origin.

As a result of all these observations it is impossible to avoid the conclusion that the nucleus is intimately concerned in differentiation, and the mechanism of the "nuclear control" of the cell is at least suggested by the escape of chromatin into the cytoplasm and the formation there of various differentiation products such as mitochondria, sphere substance, fibers, granules, etc.

(*c*) *Segregation and Isolation of Different Substances.*—Embryonic differentiation involves not only the formation of different substances in cells, but also their segregation in particular parts of cells and ultimately, in most cases, their isolation in different cells. Such segregation and isolation are seen especially well in the cleavage of the egg. By the flowing movements of cytoplasm during mitosis the various substances in the cells are oriented and sorted and by the formation of division walls between daughter cells these substances become permanently isolated. Such segregation and isolation of different cytoplasmic substances is certainly one of the most important functions of cleavage.

(1) *Differential and Non-Differential Cell Divisions.*—Cell dixisions are plainly of two kinds, differential in which the daughter cells are unlike in size or contents, and non-differential in which they are alike. Both of these occur in the cleavage of the egg but only the former contributes directly to

embryonic differentiation. Given a cell which is not homogenous, or in which every radius is not like every other one, it follows that cell divisions will be differential or non-differential depending upon the position and direction of the cleavage planes. Under normal conditions these planes are constant in position and they follow one another in a definite sequence just as do all processes of development. Consequently the pattern and character of the cleavage and its relation to differentiation is nearly constant for each species. Any explanation of the causes of differential cell-division must account for the localizations of different materials in cells and for the orientation of the planes of cell division.

(2) *The Orientations of Development.*—All of the orientations of development find their earliest visible expression in the polar differentiation of the egg. This polarity determines not only the polarity of cleavage cells, embryos and adults but it is also causally related to the direction of movement of the germ nuclei and of cytoplasmic substances, and consequently to the type of symmetry and the pattern of localization, as well as to other orientations of development. The problem of the causes of these orientations is perhaps the greatest problem of embryogeny.

Experiments with eggs subjected to centrifugal force indicate that pigment, oil, yolk and other inclusions are passively localized in certain parts of the cell and that the substance in which polarity persists is the elastic, contractile spongioplasm, which differs in structure or consistency at different poles and at different stages of the cycle of division. Protoplasmic flowing may be best explained as the result of the contractility of the spongioplasm, and the definite localization of inclusions, mitotic spindles and division planes, as caused by the polar differentiations of the spongioplasm. This polar differentiation of the spongioplasm persists and to it are to be referred in the last analysis many if not all of the orientations of development.

(3) *The Chromosome Theory of Heredity Applied to Embryonic Differentiation.*—According to the chromosome theory of heredity the inheritance factors are located in the chromosomes, and the cytological evidence shows that chromosomes always divide equally and presumably every cell of an individual contains the same kinds of chromosomes and the same kinds of inheritance factors. How then is it possible to explain embryonic differentiation? How can identical factors give rise to different products in different cells?

This is evidently due to the fact that while the division of chromosomes is non-differential, that of the cell body is often differential and the same chromosomes and genes acting upon different kinds of cytoplasm will produce different results (Fig. 10, p. 54). But differential cell-division is the result of definite movements in the cytoplasm, of definite orientations of spindles and cleavage planes, and ultimately of a definite polarity and symmetry of the cytoplasm. There is abundant evidence that these cytoplasmic orientations are not the immediate results of chromosomal activity and even if some of them may be the remote results of such activity it is logically impossible to place all the differential factors of development in non-differentiating genes.

On the other hand if embryonic differentiations are produced by the interaction of chromatin and cytoplasm, and if the chromatin does not undergo differentiation, it follows that some of the differential factors of heredity and development must be located in the cytoplasm. Such factors would probably not be genes and would not be transmitted in Mendelian fashion, but they would need to be present in the cytoplasm from the very beginnings of ontogeny. They need not be numerous—in fact they are probably few in number—but they are absolutely indispensable to development. If a few orientating differentiations such as polarity and symmetry are present in the cytoplasm at the beginnings of ontogeny all other differentiations of development can be explained as due to the interaction of non-differentiating genes on different parts of this cytoplasm, but there is no mechanism by which embryonic differentiations could come from the action of non-differentiating genes on a homogeneous cytoplasm. The genes or Mendelian factors are undoubtedly located in the chromosomes and they are sometimes regarded as the only differential factors of development, but if this were true these genes would of necessity have to undergo differential division and distribution to the cleavage cells; since this is not true it must be that some of the differential factors of development lie outside of the nucleus and if they are inherited, as most of these early orientations are, they must lie in the cytoplasm.

N. R. Graves, Photo.

THE ROCHESTER CANYON. View looking south, upstream, toward Driving Park Avenue bridge.

A NATURE DRAMA

By Professor H. L. FAIRCHILD

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The Place .... New York State.
The Time .... The Pleistocene: some little while ago.
Principal Characters:
- A vast Ice Sheet .... Quebec Glacier.
- A Lake .... Dawson.
- A second Lake .... Iroquois.
- A third Lake .... Ontario.
- Two sister Rivers .... Niagara and Genesee.
- Attendant Rivers .... Dawson Outlet; Iromohawk; Covey; St. Lawrence.
- Oceanic Waters .... Hudson-Champlain; Gilbert Gulf.
- An invisible, subterranean Force .... Diastrophism.[1]
- Attendant Atmospheric Agents .... Epigene.
- Solar Energy .... Sun Heat.

Prologue

Joseph Rodman Drake wrote "The Culprit Fay" with the purpose of producing a dramatic story without human characters. But his characters imitate humans, and the motif and movement of the story are simulation of human action. The present dramatic narration has no human relation whatever. Furthermore, it is not in the least imaginary, but is a recital of actual events, the conflict of the forces of Nature and the interaction of material agents which shape the surface of the globe. The interplay of Nature's forces and processes are as truly dramatic as anything in human action and emotion; and as the milleniums pass the human play seems petty and trivial by contrast with the changes in the earth and the cosmos. And, after all is said, Man is only a phenomenon of nature.

The reader asks for the *purpose* in the drama—the motive which impels the characters. If the reader can tell the purpose of the universe and its activities, of the motive in tide and storm and earthquake, and in the making and shaping of the continents, then he will know the purpose which animated the characters of this drama.

The story here given is merely a translation of the many conspicuous records left by the *dramatis personæ*. The in-

[1] Description of this character will be found in a ponderous volume called Webster's Dictionary.

Rock Strata, Rochester Canyon. View looking north from Driving Park Avenue bridge.

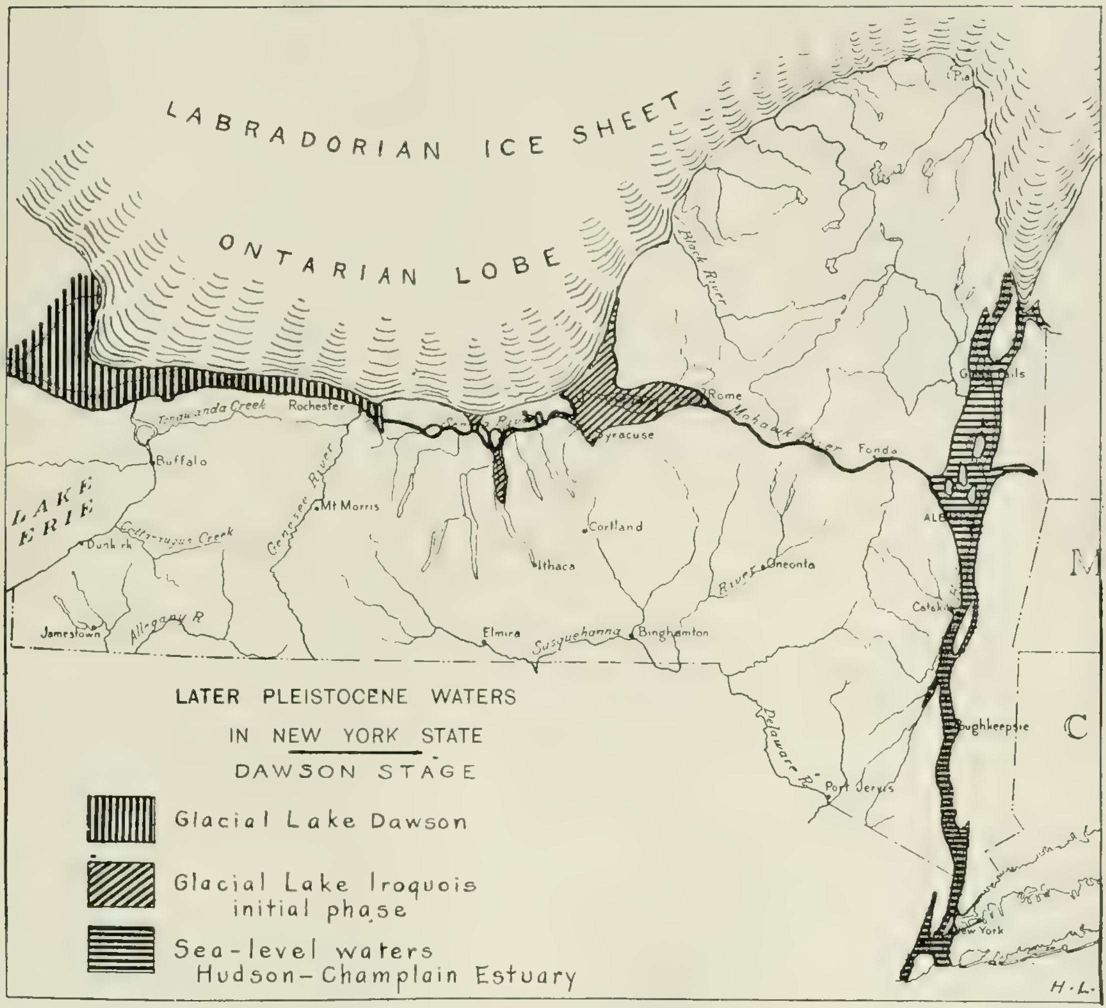


FIG. 1. DAWSON STAGE OF THE GLACIAL WATERS.

scriptions left by the glacier, the rivers, the lakes and seas, are open to observation and are not difficult of interpretation.

The portion of the great drama which is here given covers only the latest episodes in a long series of dramatic and romantic events which have been enacted on the stage of New York State. Some of the actors are yet alive and playing their parts. The earlier scenes have been partially described in the dramatic (geologic) literature.

The story may be epitomized as follows: The forces and processes of the atmosphere, here called Epigene, had created a vast ice sheet, central in Quebec, which had overridden the entire area and had long occupied the stage to the exclusion of the other characters. This dominant performer was now grudgingly yielding room to the other actors, under the compulsion of Sun Heat. Other characters appear on the stage, "strut their little day" (geologically speaking), while some of them have passed away into oblivion. The unseen "villain" of the play, Diastrophism, hereafter called Diastro, is constantly disturbing the equilibrium of the stage and interfering

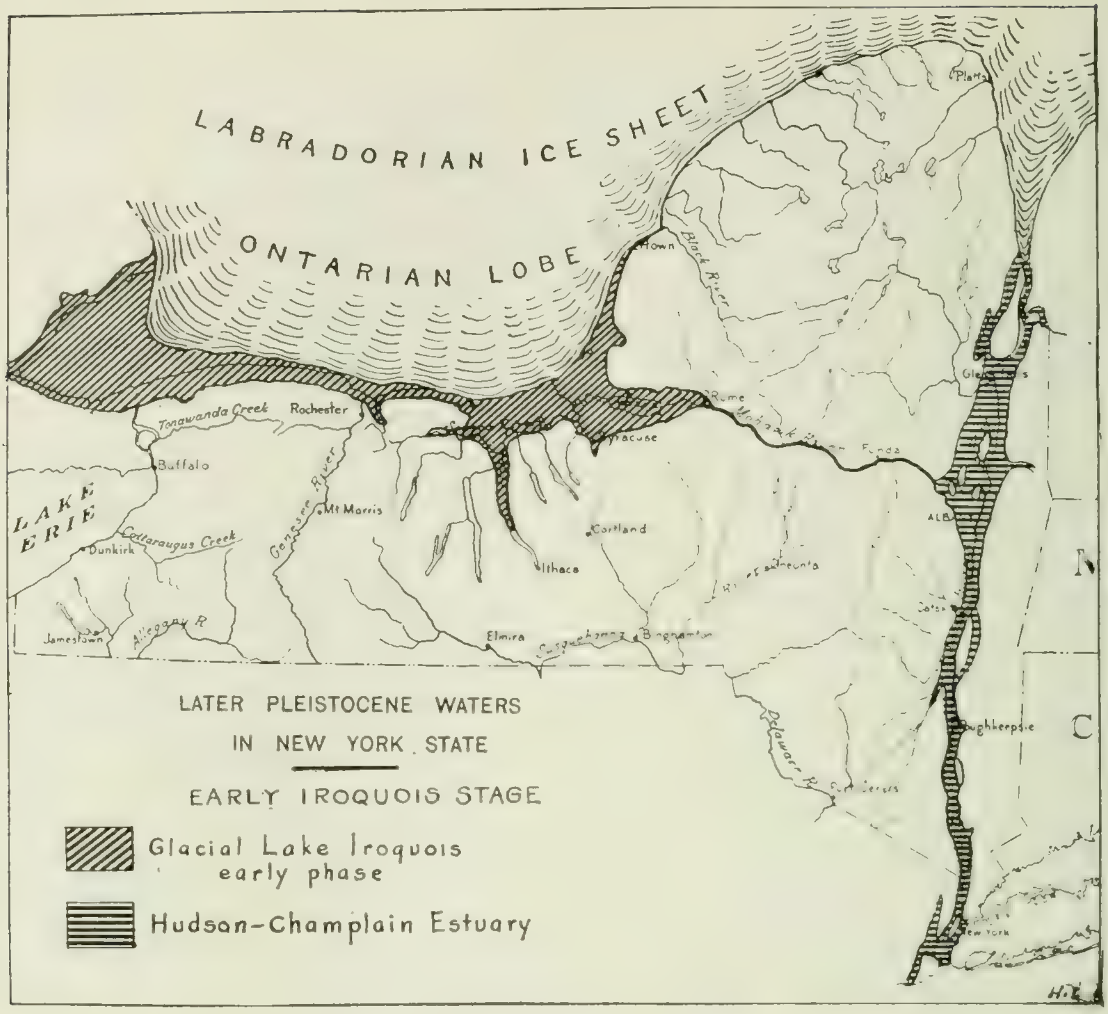


Fig. 2. Early Iroquois Stage.

with the visible actors, by raising and tilting the entire stage. This change of level, accompanied by the withdrawal of Quebec Glacier, causes rivalry and changes in the standing waters, the Lakes, and in the appearance and disappearance of the running waters, the attendant Rivers. Finally Quebec Glacier makes its exit and the aqueous and atmospheric performers take the present-time position and relation.

Act One

Scene 1

The stage setting is shown in the diagram, Fig. 1.

Color scheme: Glacier, white; Rivers, green; Lakes, blue.

Quebec Glacier holds the center of the stage.

Enter, Dawson Lake, with Iroquois, and the attendant Montezuma Lake.

Movement

The Glacier, the cold, impassive member of the dramatic group, has been losing power and control, but yet holds the contiguous waters at high levels. Dawson Lake, the successor of a long sequence of glacier lakes, is confined to the western part of the stage, in the Ontario basin, having altitude 230 feet above the sea. Into this lake pour two rivers, Niagara and Genesee. The former is very young and is now making its debut. The latter is of great age with long life on the stage. Niagara carries, as today, the outflow of the Great Lakes. The Niagara Falls and the upper Rochester cataract are in early life.

The Dawson Outlet River, flowing through Fairport, Palmyra, Newark and Lyons, carries the copious waters eastward, grading a path for human use. This river loses itself in Montezuma Lake, lying in the low ground of Seneca and Cayuga valleys, which lake is itself drained into the young Iroquois Lake, lying in the Syracuse-Rome district. Iroquois Lake has altitude 110 feet above the sea, and outflows at Rome by the Iromohawk (abbreviation for Iroquois-Mohawk) River to final repose in oceanic waters in the Schenectady-Albany district.

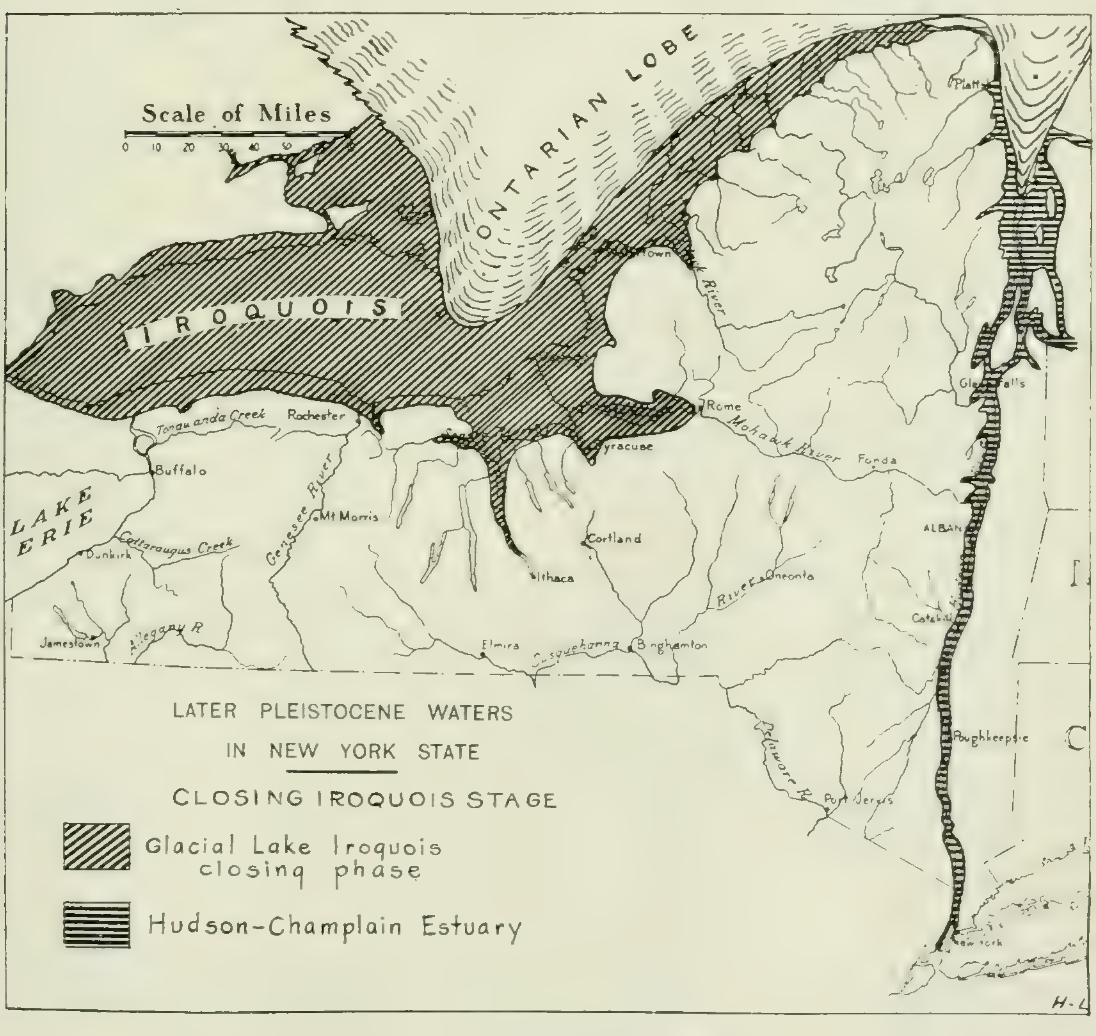


FIG. 3. CLOSING IROQUOIS STAGE.

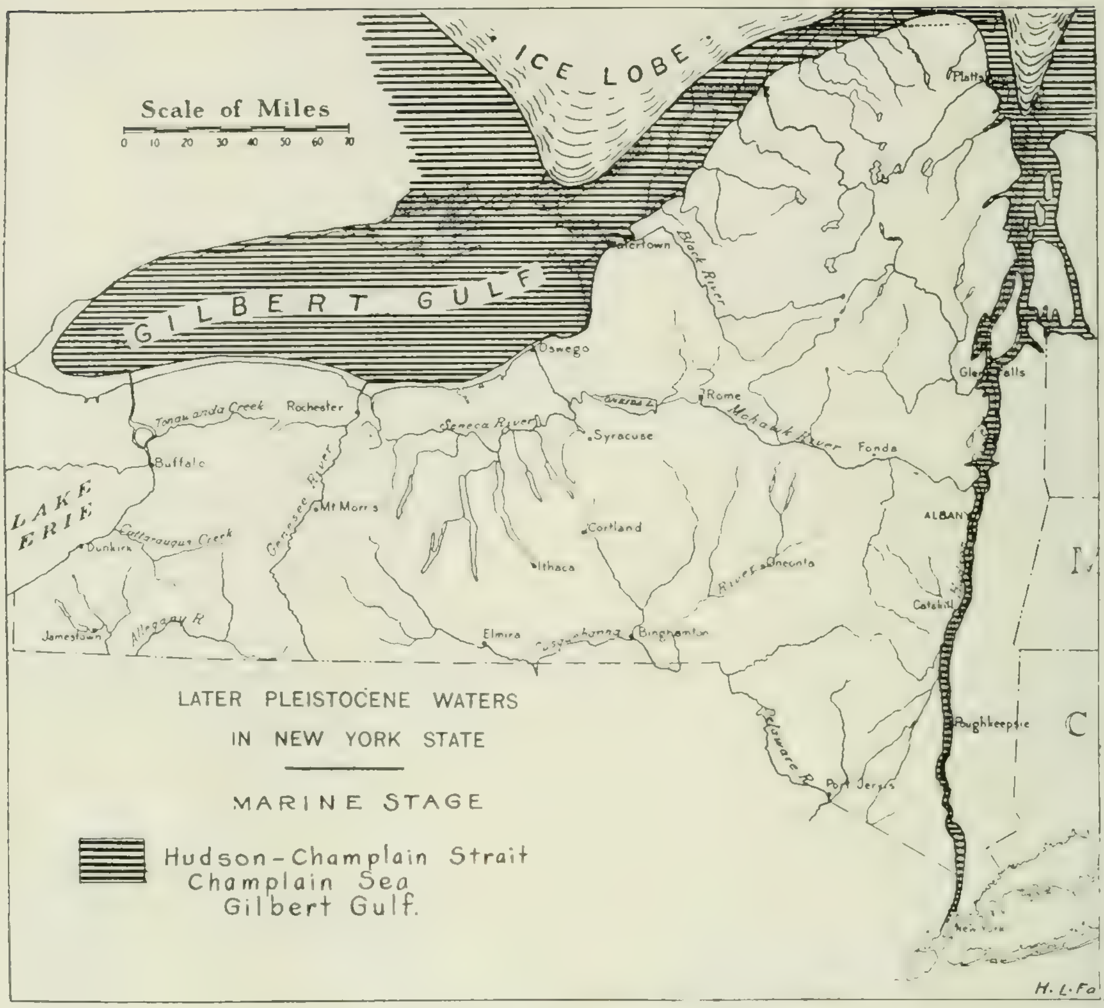


FIG. 4. GILBERT GULF, SEA-LEVEL WATERS.

These great rivers are now grading the lowest path from the Atlantic seaboard to the Great Lakes and the Mississippi Valley.

All the great area which stages this scene was much lower in altitude than it is to-day. The Iromohawk delta, the sandplain between Schenectady and Albany, was then building at sealevel, or 350 feet lower than to-day. Rome was 350 feet and Rochester 250 feet lower than now. Diastro, the strong villain of the play, begins his slow but irresistible business of lifting the stage, producing the changes in level.

The Oceanic Waters of the Hudson Estuary occupy the slowly rising Hudson Valley.

Closing the scene, Lakes Dawson and Montezuma and their attendant Rivers, exeunt.

Scene 2

This scene is depicted in the diagram, Fig. 2.

Owing to the pressure of Sun Heat the Glacier yields a few miles and the young Iroquois Lake supplants two lakes and attendant rivers of the preceding scene. Iroquois now extends the whole length of the Ontario Basin, from Rome, N. Y. to Hamilton, Canada.

With Iroquois succeeding Dawson the base-level of the Rivers Niagara and Genesee, and all the minor streams, falls from 230 feet above ocean to 110 feet, and the rivers extend their courses northward to the lower waters (see Figs. 7, 8).

Up to this time Diastro has not seriously affected the progress of the drama, the movement of the play being chiefly due to the weakening and withdrawal of Glacier.

Iroquois Lake clings to Glacier, and expands as the latter wanes.

Act Two

Scene 1

The stage setting is shown in Fig. 3.

Exit Iromohawk River.

Sun Heat and Epigene have pressed Quebec Glacier nearly off the stage. At only one point does the latter now interfere

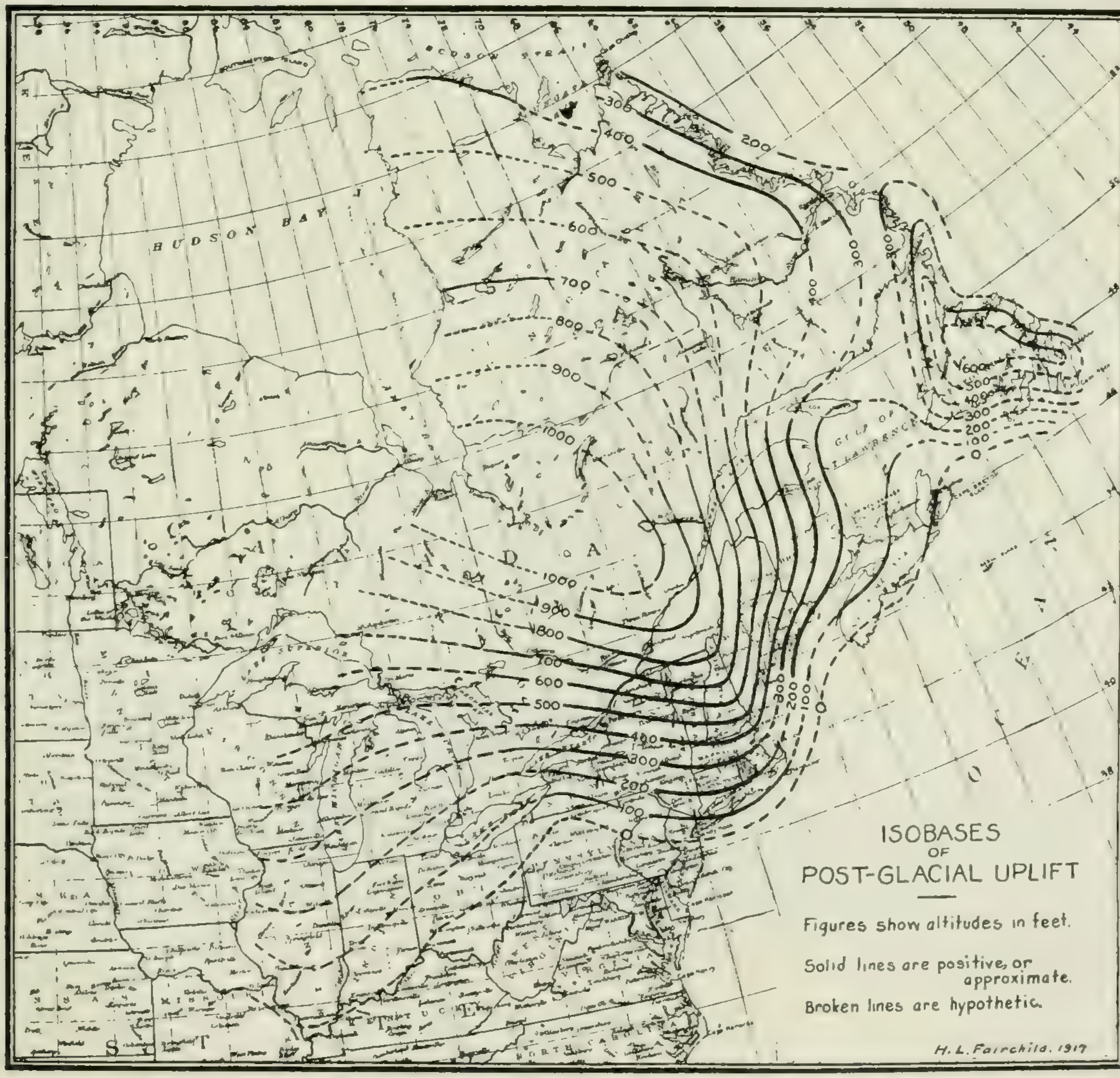


Fig. 5. Uplift of Northeastern America.

UPPER FALL, GENESEE RIVER, ROCHESTER, N. Y.

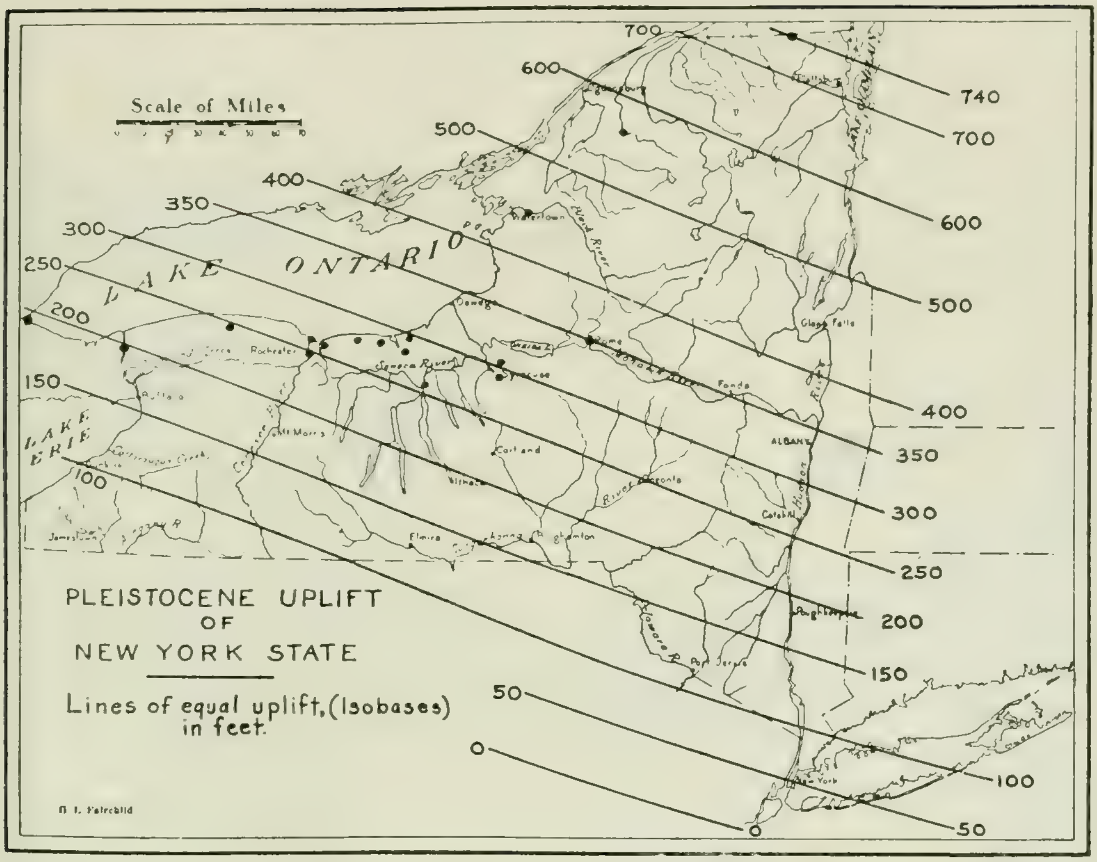


FIG. 6. TILTING-UPLIFT OF NEW YORK.

with the other performers. On the Canadian boundary of New York the Glacier is holding the outflow of Iroquois Lake to a new channel, the Covey pass. The Covey River, on account of lower altitude, is the successor to Iromohawk, carrying Iroquois water to sealevel in the Hudson-Champlain estuary.

Iroquois Lake is at its maximum.

Scene 2

The stage setting is the same as in scene 1.

Quebec Glacier is waning. Iroquois Lake is about to retire. Diastro is the leading performer (Figs. 5, 6).

By the tilting uplift, and the land rise at Rome of 180 feet, Diastro has raised the level of Iroquois Lake from 110 to 290 feet.

As the land at Rochester has risen only 105 feet the Iroquois water produces a flooding there of 75 feet. The rivers Niagara and Genesee, and their companions, are checked in flow by the rising lake, and their mouths are forced back, up the land slopes (in Figs. 7, 8 from position 2 to position 3).

Exit Iroquois. For New York State the Glacial Period has ended.

ACT THREE

Scene 1

The stage setting is shown in Fig. 4.

N. R. Graves, Photo.

Lower Fall, Genesee River, Rochester, N. Y.

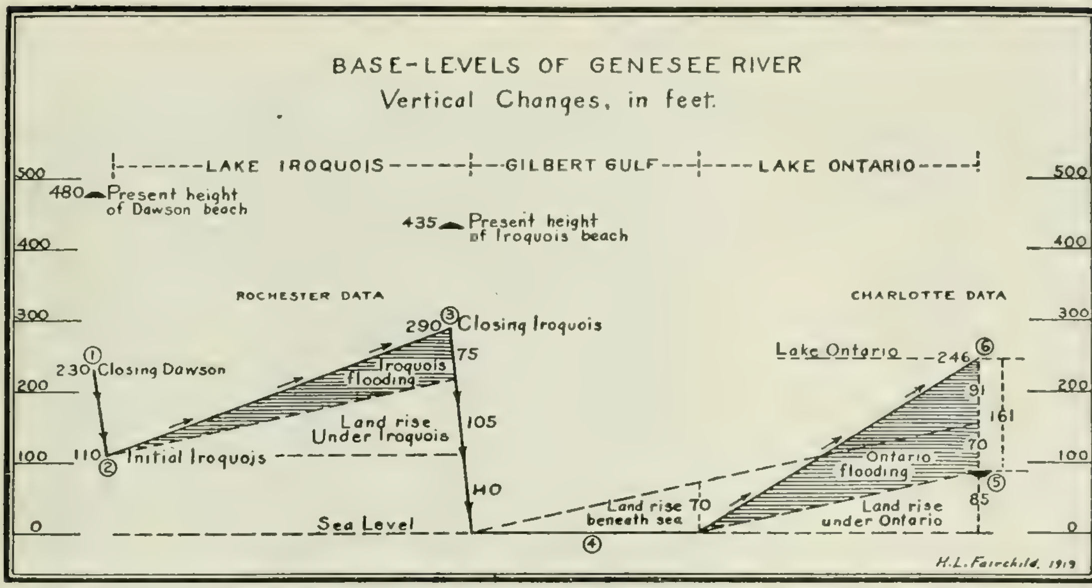


FIG. 7. VERTICAL CHANGES IN THE GENESEE RIVER BASE-LEVELS.

Enter, ocean-level water in the Ontario basin, Gilbert Gulf.

The frozen, damming member of the company has removed from the stage (the area of New York) and stands back in the wings.

Relieved of all interference the water in the Ontario basin falls to sealevel, and Gilbert Gulf succeeds Iroquois Lake. The base-level of all the rivers falls from 290 feet to zero, and the rivers extend themselves far northward to the sealevel water. (In Figs. 7, 8 the mouth of the Genesee shifts from position 3 to position 4.)

Scene 2

Stage setting the same as in scene 1.

The performers are few—the sealevel waters, Hudson-

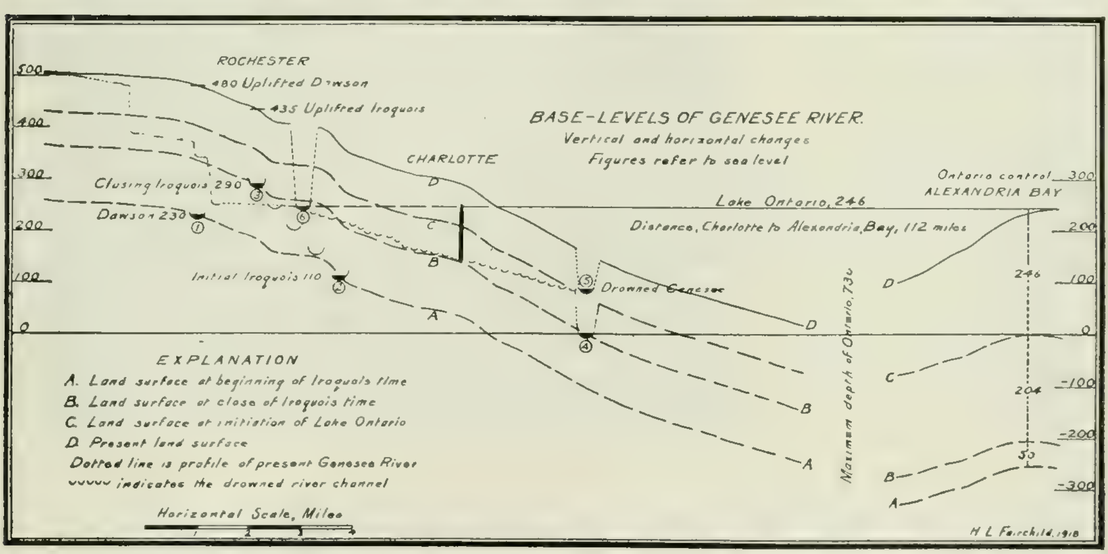


FIG. 8. VERTICAL AND HORIZONTAL CHANGES IN THE GENESSEE RIVER BASE-LEVELS.

G. H. Chadwick, Photo.

The Rochester Canyon. View looking south, upstream, toward the city. The river at level of Lake Ontario, 246 feet.

Champlain estuary and Gilbert Gulf; the rivers Niagara and Genesee and their attendants; Sun Heat and Epigene with attendants.

The movement is chiefly the action of Diastro, in lifting the northern part of the stage more rapidly. But until the district of the Thousand Islands is raised out of the sealevel waters there is no change of scene.

Scene 3

The setting of the stage is any map of the present geography of New York State.

Exit, Gilbert Gulf.

Enter, St. Lawrence River and Lakes Champlain and Ontario.

Diastro erects a barrier in the St. Lawrence Valley, at the Thousand Islands, which imprisons the waters of Gilbert Gulf and transforms them into Ontario Lake. The uplifting of the barrier continues until Ontario water is 246 feet above the sea.

The embouchures of the rivers are pushed backward, up the land slopes, as had been the case during the rise of Iroquois. (In Figs. 7, 8 the mouth of the Genesee is shifted from position 4 to position 6.)

As Charlotte, the location of the present embouchure of Genesee River, rises only 85 feet while Ontario level rises 246 feet, the flooding by Ontario water has drowned the river channel that was cut in time of Gilbert Gulf (Fig. 4) under 161 feet of water. (The drowned position is indicated by position 5 of the diagrams, Figs. 7, 8).

The quantitative vertical elements showing the total work of Diastro are given in Figs. 5, 6, 7 and 8.

EPILOGUE

Here ends the translation. But the actual drama does not end with this brief relation. The drama is yet in progress, superior to any human cooperation or opposition; and it will continue for millions of years after humanity has run its course and disappears from the earth. The movement of the play takes no note of time. In the far future the stage of New York area may carry changes as dramatic, or perhaps greater, than those recorded in the immediate past.[1]

[1] The detailed story of the events here epitomized is published in *Proceedings of the Rochester Academy of Science,* Volume 6, 1919, pages 1–55, and the general history is given in Bulletin No. 209–210 of the New York State Museum.

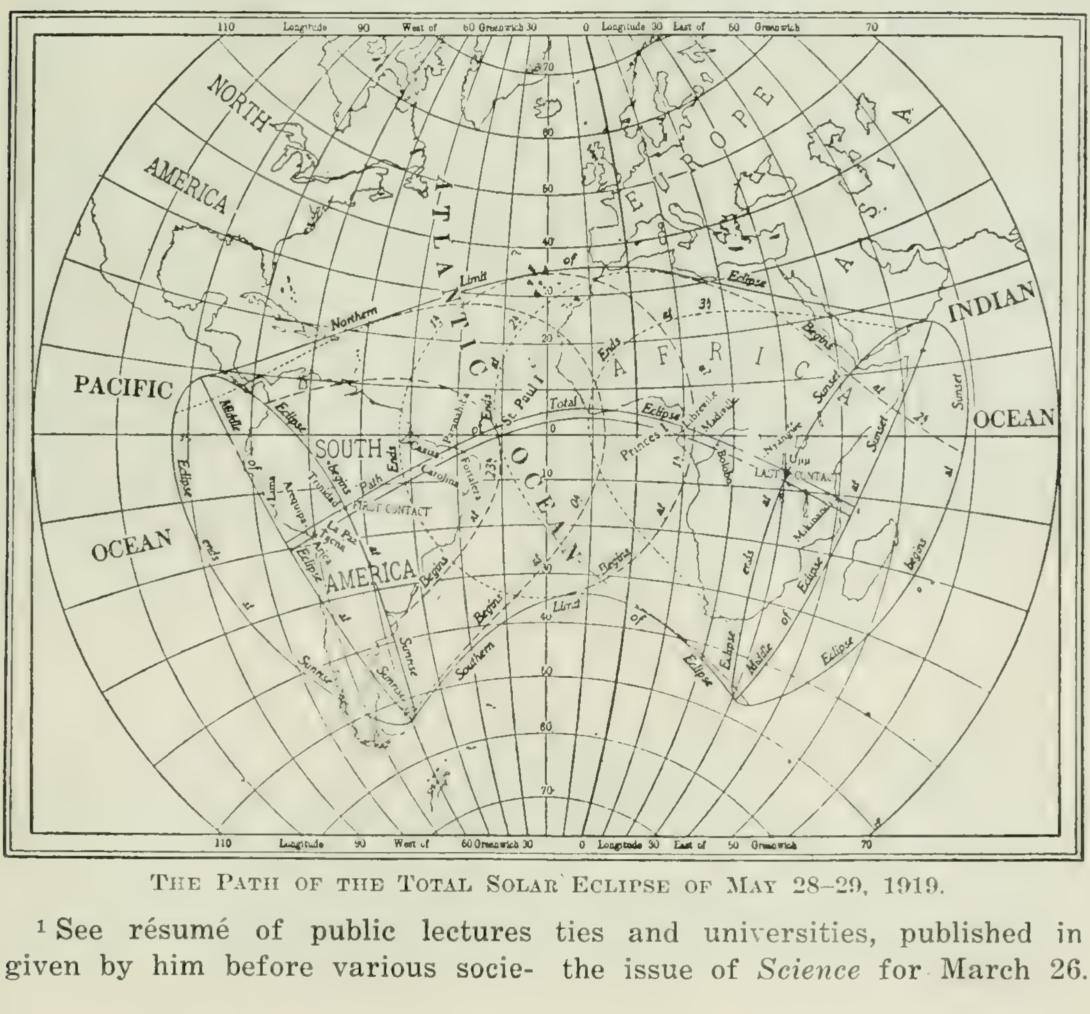
Professor Albert Einstein,
University of Berlin.

THE PROGRESS OF SCIENCE

THE SOLAR ECLIPSE OF MAY 29, 1919, AND THE EINSTEIN EFFECT

THE supposed verification, by British astronomers during the solar eclipse of May 29, 1919, of the Einstein prediction that rays of light, while passing near the sun, would be bent out of their straight course by the sun's gravitational pull, like any flying projectile, has made, says Dr. L. O. Bauer,[1] an eclipse of the sun of more than passing interest, not alone to the astronomer, but also to the geophysicist, the mathematician, the physicist, and, in fact, to the philosopher, in general.

If a star-ray, on its way to the earth, just grazed the sun's limb, then the star, as seen by a terrestrial observer, or caught on a photographic plate, would either not be displaced at all, or it would be displaced by a certain minute amount, *a*. If the principles of the Newtonian mechanics hold for particles moving with the velocity of light (186,000 miles a second), then on the basis of Maxwell's electromagnetic theory of light, the apparent displacement, *a*, away from the sun would amount to 0″.87; this was the shift predicted by Einstein in his first theory of relativity. According to his later or generalized theory of relativity, which brings under the same purview electromagnetic and gravitational phenomena, the star would be displaced apparently by the amount 2*a* or 1″.74. If the ray of light passed through the sun's gravitational field at the distance from the



THE PATH OF THE TOTAL SOLAR ECLIPSE OF MAY 28–29, 1919.

[1] See résumé of public lectures given by him before various societies and universities, published in the issue of *Science* for March 26.

THE SOLAR CORONA DURING THE ECLIPSE OF MAY 29, 1919, as photographed by Dr. C. G. Abbot, of the Smithsonian Institution, at an elevation of 14,000 feet, near La Paz, Bolivia.

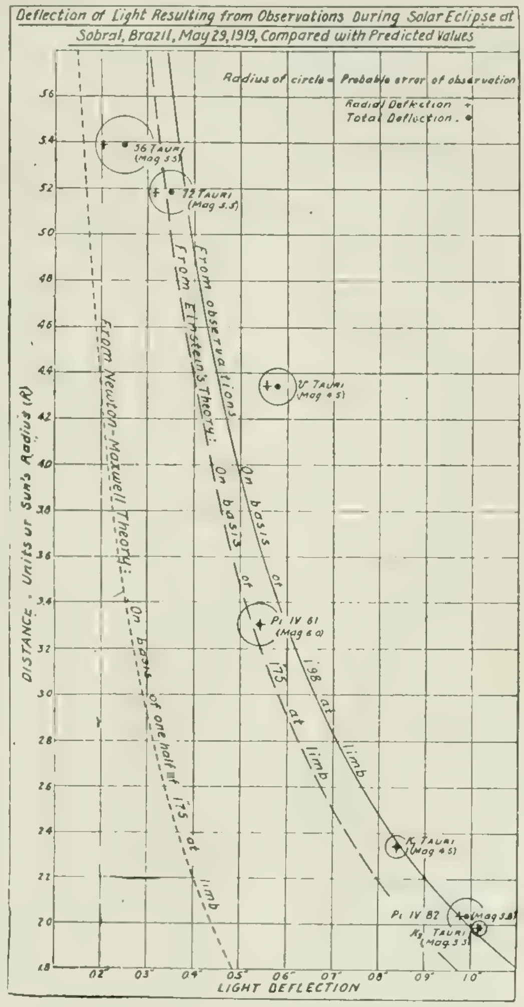
center of the sun twice its radius, as was about the case for the nearest star concerned in the British observations, the apparent displacement would simply be one half of the amounts just stated. In brief, the deflection would vary inversely as the distance.

Now, according to the results from the best of the photographic plates obtained by the two British expeditions, one to Sobral, Brazil, and the other to the Île of Principe, west coast of Africa, the displacements of the stars accorded best with the predictions based on Einstein's later theory. The British astronomers were exceedingly fortunate in having the opportunity of making the tests during an eclipse when there was a rich field of bright stars, the Hyades, sufficiently close to the sun, so that the quantities to be measured were well within the observational errors.

Professor W. W. Campbell's expedition made a test during the solar eclipse of June 8, 1918, at Goldendale, Washington, but, unfortunately, his observations had to be made on ninth magnitude stars, distant from the sun, two times or more the farthest star used by the British. His party was therefore obliged to work with much more minute quantities. The result from all of the observations was a mean displacement of 0″.05 in the right direction; but agreeing better with the predicted value (0″.08) on the basis of the Newtonian principles, than with that (0″.15) computed according to Einstein's later theory.

The combined result of the British and American tests would accordingly be that *light has weight,* besides exerting a measurable pressure; just how much weight depends upon whether the Newtonian or the Einstein principles are ultimately found correct. Astronomers are stimulated to make further tests in view of the important astronomical consequences of the Einstein theory; preparations by British astronomers are already under way for observations during the solar eclipse of September, 1922, which will occur in Australia, though the stellar conditions will not be as favorable as they were last year.

The importance of the subject has naturally caused some to advance possible other causes for the observed light deflections. Thus such an eminent solar physicist as Dr. H. F. Newall, of the Cambridge Observatory, while he is disposed to admit a possible effect according to Newtonian mechanics, prefers considering that the balance of the observed deflection of light is attributable to refraction in the solar atmosphere as mapped out, for example, to a certain extent by the solar corona.



THE CHART, CONSTRUCTED BY THE DEPARTMENT OF TERRESTRIAL MAGNETISM, OF THE CARNEGIE INSTITUTION, gives a graphical representation of the law of variation with distance followed by the observed deflections for each star. Excepting the most distant star (56 Tauri), each star shows a deflection agreeing better with the Einstein value than with the Newton-Maxwell one. The probable error of observation is shown by the size of the circle around each star.

It would also appear, according to Dr. Bauer's investigations, that the observed deflections are not strictly radial, *i.e.*, not wholly in the direction of the sun's radius, indicating that there are some effects superposed upon the simple Newton, or Einstein, effects. He finds that the non-radial effects occur in a systematic manner and not accidentally as they would if they were purely observational errors. He also finds that for the same distance a star in the polar regions of the sun showed a somewhat larger displacement than one in the equatorial regions. The question is raised, among others, how completely it was possible in the British observations to eliminate differential refraction effects as the rays passed through the earth's atmosphere.

Dr. Bauer's expedition was one of several expeditions sent out by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington to make geophysical observations, the data from which are proving of interest in the discussion of the possible disturbing effects on the observed deflections of light. He himself observed the memorable eclipse at Cape Palmas, Liberia, where totality lasted longer, 6 minutes and 33 seconds, than at any other accessible station. He characterizes this eclipse as the most magnificent one of the four he has thus far observed; not only was the corona beautifully and finely developed but also a striking crimson prominence appeared on the sun's southeast limb which shot up 100,000 miles and had a base of 300,000 miles.

Dr. Bauer concludes with reference to the observed light deflections that " the best attitude to take is that of open-mindedness and to let no opportunity pass by for further experimental tests," and that " one of the most satisfactory results has been the stimulus imparted to further research in many fields which is bound to bear fruit."

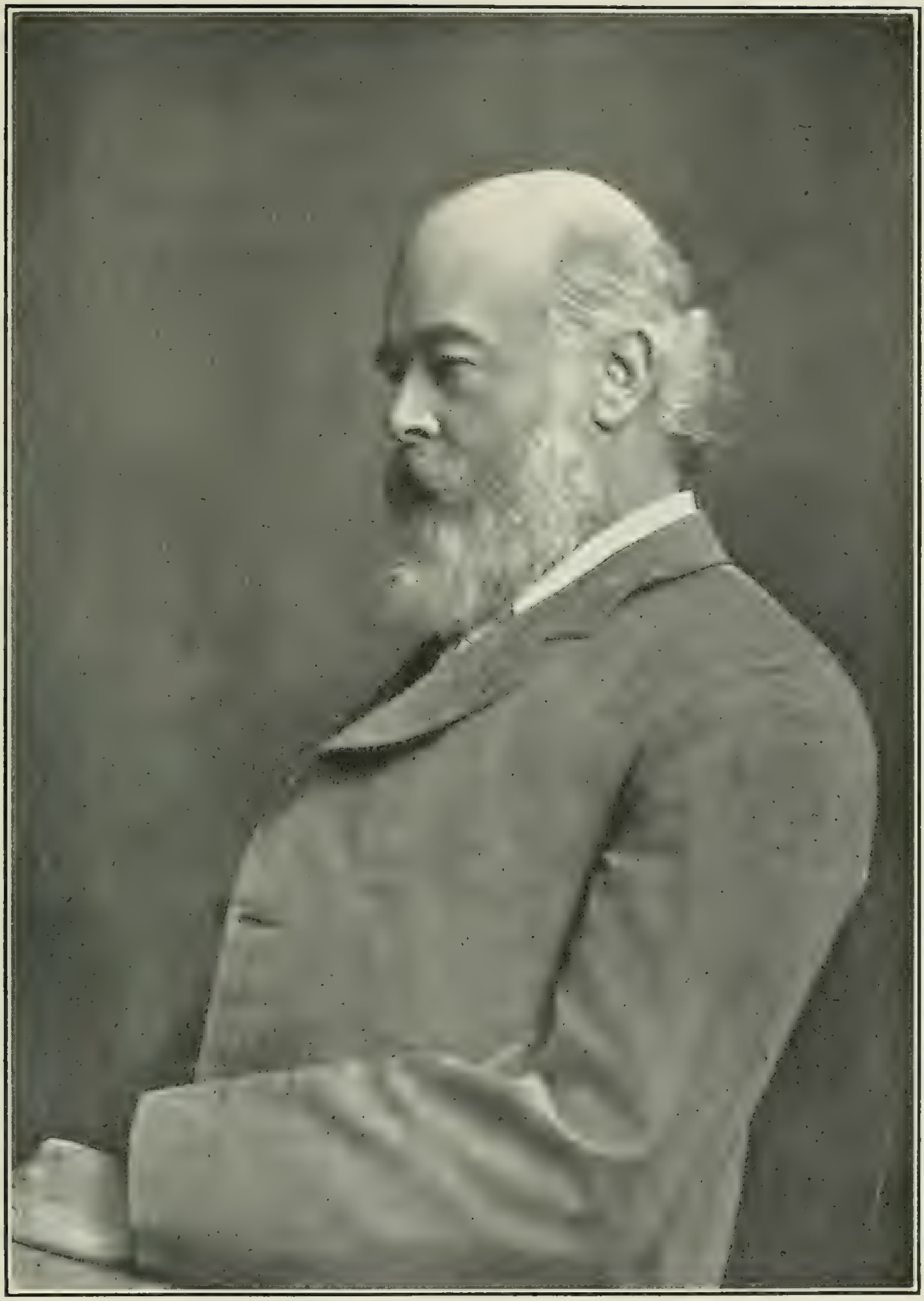
PROFESSOR EINSTEIN ON THE THEORY OF RELATIVITY

In an article contributed to the London *Times*, Professor Albert Einstein has undertaken to present his theory of relativity in a form comprehensible to readers not trained to think in mathematical formulas. He calls attention to the fact that the ancient Greeks knew that the motion of a body must be described in reference to another body. In physics the bodies to which motions are spatially referred are termed systems of coordinates. The laws of mechanics of Galileo and Newton can be formulated only by using a system of coordinates.

The special relativity theory is the application of the following proposition to any natural process: " Every law of nature which holds good with respect to a coordinate system K must also hold good for any other system K' provided that K and K' are in uniform movement of translation." According to the Maxwell-Lorentz theory of electro-dynamics, however, light in a vacuum has a definite and constant velocity, independent of the velocity of its source.

These two principles have received experimental confirmation, but do not seem to be logically compatible. The special relativity theory achieved their logical reconciliation by making a change in kinematics, that is to say, in the doctrine of the physical laws of space and time. It became evident that a statement of the coincidence of two events could have a meaning only in connection with a system of coordinates, that the mass of bodies and the rate of movement of clocks must depend on their state of motion with regard to the coordinates.

But the older physics, including the laws of motion of Galileo and Newton, clashed with the relativistic kinematics. Physics had to be modified. The most notable change was a new law of motion for very rapidly moving mass-points, and this soon came to be verified in the case of electrically-laden particles. The most important result of the special relativity system concerned the inert



Sir Oliver Lodge.

Formerly professor of physics in the University of Liverpool and principal of the University of Birmingham.

mass of a material system. It became evident that the inertia of such a system must depend on its energy-content, so that we were driven to the conception that inert mass was nothing else than latent energy. The doctrine of the conservation of mass lost its independence and became merged in the doctrine of conservation of energy.

The special relativity theory which was simply a systematic extension of the electro-dynamics of Maxwell and Lorentz, had consequences which reached beyond itself. Although it may be necessary for our descriptions of nature to employ systems of coordinates that we have selected arbitrarily, the choice should not be limited in any way so far as their state of motion is concerned. This general theory of relativity was found to be in conflict with a well-known experiment, according to which it appeared that the weight and the inertia of a body depended on the same constants.

A generalized theory of relativity must include the laws of gravitation, and actual pursuit of the conception has justified the hope. But the way was harder than was expected, because it contradicted Euclidian geometry. In other words, the laws according to which material bodies are arranged in space do not exactly agree with the laws of space prescribed by the Euclidian geometry of solids. This is what is meant by the phrase "a warp in space." The fundamental concepts "straight," "plane," etc., accordingly lose their exact meaning in physics.

In the generalized theory of relativity, the doctrine of space and time, kinematics, is no longer one of the absolute foundations of general physics. The geometrical states of bodies and the rates of clocks depend in the first place on their gravitational fields, which again are produced by the material systems concerned.

Thus the new theory of gravitation diverges widely from that of Newton with respect to its basal principle. But in practical application the two agree so closely that it has been difficult to find cases in which the actual differences could be subjected to observation. As yet only the following have been suggested: (1) The distortion of the oval orbits of planets round the sun (confirmed in the case of the planet mercury). (2) The deviation of light-rays in a gravitational field (confirmed by the English Solar Eclipse expedition). (3) The shifting of spectral lines towards the red end of the spectrum in the case of light coming to us from stars of appreciable mass (not yet confirmed).

Professor Einstein says in conclusion: "The great attraction of the theory is its logical consistency. If any deduction from it should prove untenable, it must be given up. A modification of it seems impossible without destruction of the whole. No one must think that Newton's great creation can be overthrown in any real sense by this or by any other theory. His clear and wide ideas will for ever retain their significance as the foundation on which our modern conceptions of physics have been built."

SCIENTIFIC ITEMS

We record with regret the death of Francis C. Phillips, for forty years professor of chemistry at the University of Pittsburgh; of Alfred J. Moses, professor of mineralogy in Columbia University; of Edwin A. Strong, emeritus professor of physics at the Michigan State Normal College; of Sir James Alexander Grant, the Canadian surgeon and paleontologist; and of two of the most distinguished German men of science, Wilhelm Pfeffer, the botanist of the University of Leipzig, and of Otto Bütschli, the zoologist of the University of Heidelberg.

THE SCIENTIFIC MONTHLY

MAY, 1920

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN[1]

By Professor JOHN C. MERRIAM

UNIVERSITY OF CALIFORNIA

Pleistocene Stages in Human History Subsequent to the Time of Heidelberg Man. III.

THE earliest remains of man, known in the *Pithecanthropus* of Java and the Heidelberg type, are generally considered to represent stages of time not ranging far from the beginning of the Pleistocene period, or the geological division immediately preceding the present. It has been suggested that *Pithecanthropus* is of Pliocene age. The Heidelberg jaw was considered by Schoetensack to be possibly Pliocene, but is presumably not older than early or middle Pleistocene. With the exception of these two cases, the numerous occurrences of human remains found in deposits antedating the beginning of the present geological period are all generally considered to be of middle to late Pleistocene age.

Excepting a few widely scattered occurrences, ranging from Australia through Asia and Africa, the collections representing Pleistocene man have been secured from formations of western Europe, and discussion of the next stages in human history is as yet mainly concerned with early man in Europe. This record fortunately occurs in a division of the geological story to which extraordinarily close attention has been given by reason of the interesting fluctuations of climate marking this portion of time. Before proceeding with a discussion of the occurrences of human remains and the nature of the evolutionary sequence, it is desirable to sketch in a preliminary way an outline of the climatic and geographic history of this period, in

[1] Delivered before the National Academy of Sciences in April, 1918, as the sixth series of lectures on the William Ellery Hale Foundation.

Geological Periods	Climatic Stages	Cultural Stages	Human Types
Recent	Postglacial	Age of Metals Neolithic	Modern Races
Pleistocene	4. Glacial	Palaeolithic: Azilian, Magdalenian, Solutrean	Cro-Magnon
	Interglacial	Aurignacian, Mousterian	Neanderthal
	3. Glacial	Acheulean, Chellean	
	Interglacial		Heidelberg
	2. Glacial		
	Interglacial		
	1. Glacial		
Pliocene		Eolithic	Pithecanthropus

FIG. 1. TABLE ILLUSTRATING RELATION OF STAGES IN HUMAN EVOLUTION TO DIVISIONS OF GEOLOGICAL TIME.

which we find man passing through some of the most significant stages in the whole course of his evolution.

FLUCTUATIONS IN ENVIRONMENT OF PLEISTOCENE MAN IN EUROPE

The story of glacial history in Europe corresponds closely with that of America, and is too well known to require more than the general statement that during at least four stages in this epoch, climatic conditions were of such a nature that accumulation of snow and ice in enormous quantities was permitted at altitudes far below the present snow line. The extent to which the climate differed from that of the present time varied for the several glacial stages, but in the most extreme advance ice seems practically to have covered the northern half of Europe, extending over the British Isles and across the continent through Belgium, Germany and Russia. Ice also reached down from the Alps and other ranges to levels much below those at present touched by glaciers. Between the ice epochs, the climatic pendulum, swinging in the return beat, brought conditions in some cases more closely approaching those of the warm temperate regions than we find represented in the present climate of western Europe. It is important to note that it was in this time of frequent and radical changes in climatic conditions, and therefore of variation in the whole environment, including animal and plant life, that the present high level of human evolution was attained.

In the period of climatic changes of Pleistocene time the form of the land and distribution of water of the European region also varied much. Particularly in and near the second and third interglacial stages the British Isles and Iceland seem to have been connected with the mainland in the region of France and Belgium; the North Sea was dry, and land extended across from Scandinavia to England. During this period, the boundaries of the sea were in general moved farther out along the borders of the continent than at the present time. There seems also to have been land connection between Spain and northern Africa and between Africa and Italy.

During this period, we find not alone the climatic and geographic conditions subject to modification, but the whole scheme of animal and plant life shifted greatly from stage to stage. As would be expected, during the cold periods waves of migration swept across the continent of Europe from the north, and the Arctic animals extended their range to the lower lands; while during the stages of warm climate southern life reached north to England and middle Europe. Not only was the life shifting through migration of climatic zones, but great groups of species in many divisions of the animal and plant world disappeared, giving place to forms not known in previous time. These in turn became extinct and were largely replaced by new types before the beginning of the present geologic day.

DEPOSITS CONTAINING REMAINS OF LATER PLEISTOCENE MAN IN EUROPE

The geologic record of Pleistocene time out of which we read our human history is obtained from a great variety of evidences, including the accumulation of deposits in seas, lakes, rivers, and upon the land. It is read also from physiographic records shown in the sculpturing of land forms by wind, water, and ice; and in the history of a continuously changing living world, both plant and animal. The sequence of deposits in which entombed organisms have been discovered is complicated and difficult to read. It is moreover not the same record

2 3

4 5

FIGS. 2 TO 5. CAVE DWELLINGS IN THE VEZERE VALLEY, FRANCE. Fig. 2, Cave adapted for modern home. Fig. 3, Laugerie Haute, a modern dwelling on the site of cave deposits representing the stage of Cro-Magnon man. Fig. 4, Cave at Le Moustier, with deposits of Neanderthal stage. Fig. 5, Floor of Le Moustier covered with flaked flints.

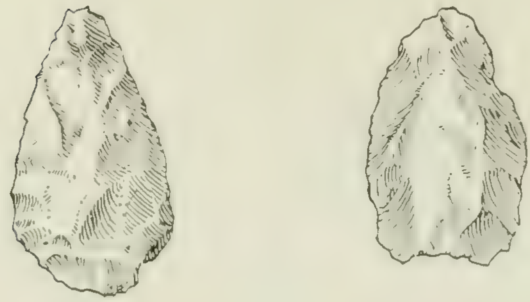
in all localities. Correlations or comparisons between widely separated regions are made with difficulty. It is, nevertheless, true that with the combined use of all known agencies, including the thermometer of climate in glacial history and the record of evolution shown in plants and animals, it has been possible through what amounts to international cooperation to work out a history with some degree of satisfaction.

The human remains of greatest significance in Europe have been found in deposits of two kinds, one consisting of stream accumulations of clay, sand, and gravel; the other the piling up of earth, gravel, sand, and stalagmite deposits in caves.

The relative age of stream deposits, and of their entombed remains, may be determined by the sequence of layers resting one upon another in a single area; or may be indicated by a succession of terrace deposits representing remnants of accumulated strata left stranded in the cutting of a valley. In general, we may not expect the best records of man to be found in formations made by streams. Although traces of skeletons are met occasionally, the destructive action of a stream is generally pronounced. Remains of implements, especially those of stone, being more resistant than skeletons, are better known in stream deposits.

The most important source of human relics of Pleistocene time is found in the numerous caves of limestone formations in western Europe. Caverns have always been places of abode for many groups of higher animals, furnishing as they do shelter from the weather and protection against enemies. Caves have been unusually significant in study of the life of early periods because they have served as concentration points for the remains not merely of their owners, but of the whole range of other animals supplying food from the surrounding country. Cave deposits are also of exceptional significance for the reason that in limestone regions, lime-burdened water dripping from the roof upon bones or other relics has often encased them with a calcareous or stalagmitic covering.

Man like other creatures seems early to have learned the advantage of cavern life. In the cave he also accumulated heaps of bones representing the animals upon which he preyed, and his bones like those of other animals were entombed in earth, clay, gravel, and stalagmite deposits in the floor of the room that was once his home. In our search for evidence concerning the history of man in the long period through which he worked his way up to domination of the natural world, no information has been found to exceed in interest the records held for ages in safe keeping in the caves. A story of the beginning history of our race comes to us from these sources filled with the thrill of adventure, and showing always the upward striving of becoming man.



FIGS. 6 AND 7. FLAKED FLINTS OF THE RIVER DRIFT STAGE. Adapted from Reinach.

RIVER DRIFT MAN

In the divisions of the geologic record succeeding those from which we have obtained *Pithecanthropus* and the Heidelberg man there are several stages at which relics apparently representing human handwork have been found without accompanying skeletal evidence of man himself. Such remains are the flaked flints of Chellean and Acheulean types discovered especially in stream deposits of the Somme Valley in northern France and in the south of England. These objects are found in deposits evidently younger than those from which the earlier eoliths are obtained and show clear evidence of purposeful shaping. They are flaked in such manner as to leave no doubt concerning the influence of an intelligent creature like man in their forming. They were evidently produced by beings of the human type inhabiting Europe subsequent to the time of Heidelberg man and before the stage of the typical Neanderthal race.

NEANDERTHAL MAN

Following the stage of Heidelberg man the earliest human relics of which we have evidence in skeletal characters are those representing the Neanderthal race. This type is now well known by skulls and other skeletal parts from numerous cave deposits of western Europe. With these remains there have been found also abundant traces of implements and of the contemporaneous animal life of this period. The materials available have made possible a very satisfactory interpretation of the physical characteristics, industry, mentality, and environment of the race.

The Neanderthal type has been best known by a now famous skeleton obtained in 1856 in a cave near Düsseldorf. Other specimens of similar type are the Gibraltar, Spy, Chapelle-aux-Saints, and Le Moustier remains, together giving full opportunity for interpretation of the characters of this remarkable race. All of these skeletons represent beings distinctly human, and with moderately large brains, but possessing exceedingly

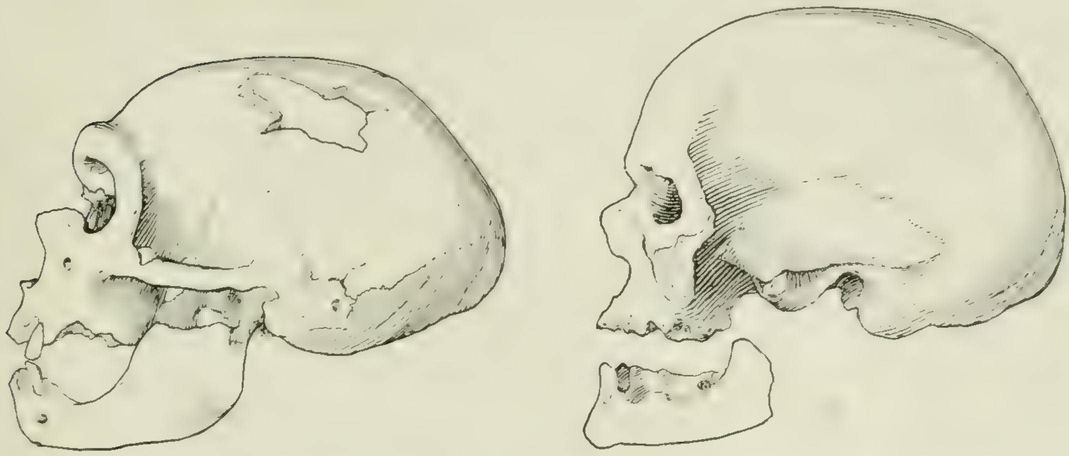


FIG. 8. SKULL OF NEANDERTHAL TYPE FROM CHAPELLE-AUX-SAINTS, FRANCE, × ¼. Adapted from Boule.
FIG. 9. SKULL OF CRO-MAGNON MAN FROM LES EYZIES, FRANCE, × ¼.

low and generally depressed skulls with extraordinarily large ridges over the eyes.

Associated with the remains of Neanderthal man in the cave deposits at various localities there have been found great quantities of flaked flints which were evidently the characteristic implements utilized by this race. In the famous cavern at Le Moustier enormous numbers of flints are known, of which some are discarded implements and others are probably the byproducts of implement manufacture. They all indicate a stage of development in which the flaking is sufficiently advanced to give a clean, sharp cutting edge undoubtedly used for a wide variety of purposes.

In the same deposits with the remains of Neanderthal man, and with the relics of his culture, there are found abundant skeletal parts of the animals of the surrounding region which provided food and probably clothing. Other animal remains found in the caves may have been accumulated by carnivorous mammals occupying these shelters in intervals between periods of human habitation. From the evidence available we know

FIGS. 10 AND 11. FLAKED FLINTS FROM FLOOR OF THE CAVERN OF LE MOUSTIER, × ½.

FIGS. 12, 13 AND 14. COMPARISON OF SKULL OF NEANDERTHAL MAN WITH A CHIMPANZEE, TO THE LEFT, AND A MODERN MAN, TO THE RIGHT.

that Neanderthal man was associated with the reindeer, woolly rhinoceros, woolly mamoth, horse, stag, giant deer, bison, cave bear, cave lion, and cave hyena. A large percentage of these animals are now extinct and are characteristic of the later Pleistocene of Europe.

In many respects the Neanderthal type presents the most striking illustration of connection between the later stages of human evolution and the history of mammalian groups which in their development trend toward man in the distinctly pre-recent portion of the record of life. The history of the Neanderthals lies well within a geological period distinctly separated from the present, the environment of this man was physically and biologically a world differing from the present, and the man himself differed markedly from any existing race. In very many ways the Neanderthals express that remoteness of time, difference of surroundings, distinct difference of physical char-

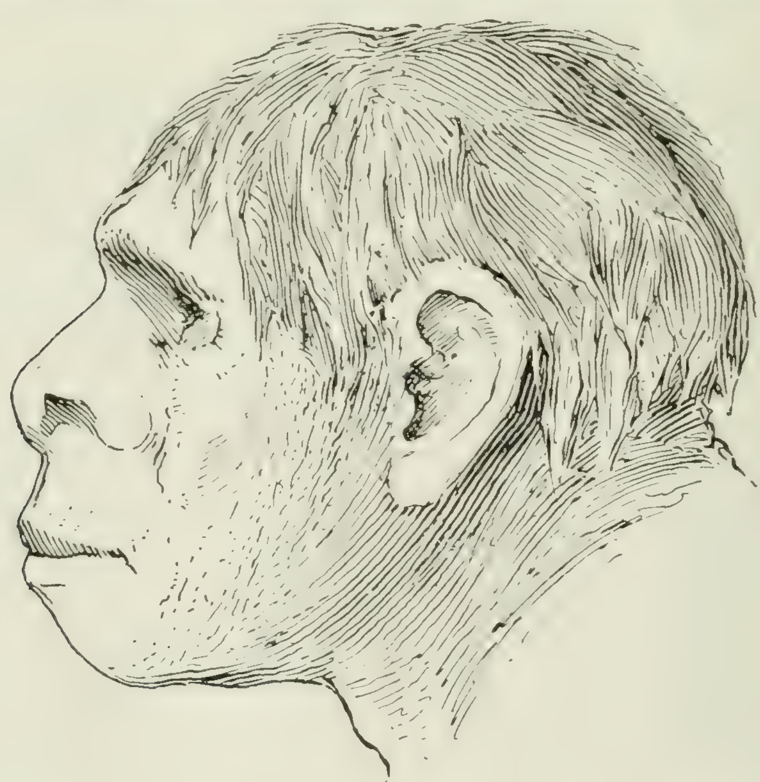


FIG. 15. RESTORATION OF NEANDERTHAL MAN. Drawn by Frieda Lueddemann, under the direction of the author.

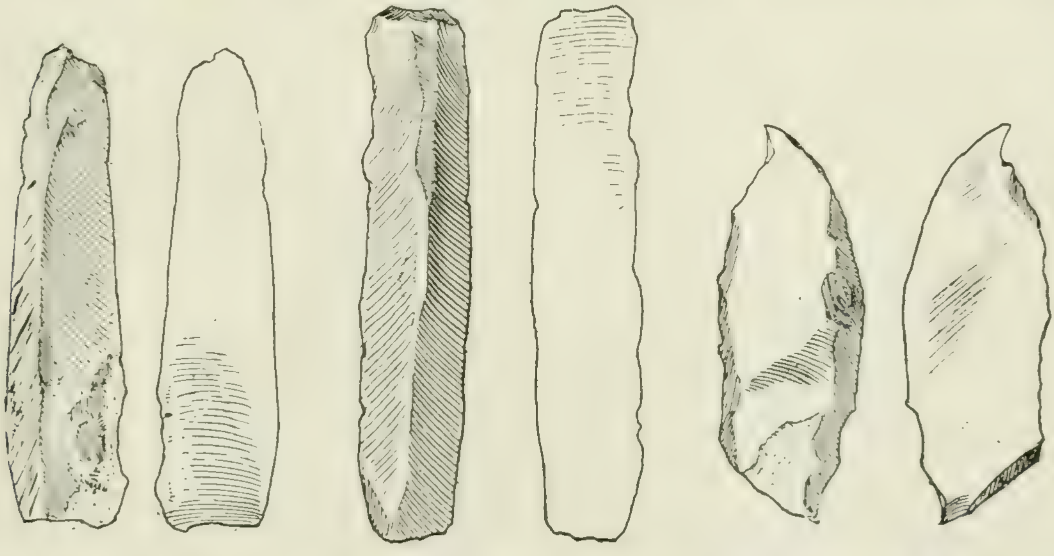
acteristics, inferior level of industry, and limitation of mental development, which one might expect to find somewhere between *Pithecanthropus* and modern races if the existing human group represents progressive development out of a more ancient and less human stock.

CRO-MAGNON MAN

At numerous localities in western Europe we find abundant evidence that a type of human being differing widely from the typical Neanderthals occupied this region between the time of Neanderthal man and the present epoch. These remains are found in cave deposits, and like those of the Neanderthals are associated with abundant implements and with the remains of a wide variety of animals which as their contemporaries furnished food and clothing.

The history of this later type is known in several stages, of which one of the most important is that represented by the famous Station of La Madeleine, only a short distance from Le Moustier on the Vezere River in the French province of Dordogne. The skeletal remains of this race generally represent individuals of large size, with skulls corresponding in outline to highly developed types of the present period. The brain case, like that of modern man, has a large content, and the form of the brain corresponds to that of the vigorous mental types of the present day.

Judging from physical characters alone one could not avoid the conclusion that this Cro-Magnon type represents a form of man skilled in thinking and in the expression of thought through action. It is, therefore, not surprising to find associated with this race a wide range of beautifully formed implements shaped



FIGS. 16, 17 AND 18. TYPICAL MAGDALENIAN FLAKED FLINTS FROM THE STATION OF LA MADELEINE, FRANCE, × ½.

from stone and from the bones of animals hunted. The stone implements show an advance in the art of chipping or flaking developed in various forms, some delicately flaked, others giving long clean-cut lines and sharp edges. Implements of bone and antler are abundant and rival in their form and ornamentation the beautiful carvings of modern Eskimo. We find also on implements and on fragments of bone and antler extraordinary expressions of an artistic instinct represented in drawings of the contemporary animals and even of people. These illustrations show us the reindeer, the mamoth, and the bison, as living creatures fully known to Cro-Magnon man and pictured by him in characteristic attitudes of action. Even more remarkable if possible are the wonderful series of drawings and paintings left by this race on the walls of many caves which were evidently not habitations but served some mysterious purpose not yet fully understood.

The remains of animals associated with the Cro-Magnons include reindeer in abundance, horses, the woolly elephant, woolly rhinoceros, cave bear, lion, and many other creatures representing a fauna in large part extinct, and of which the

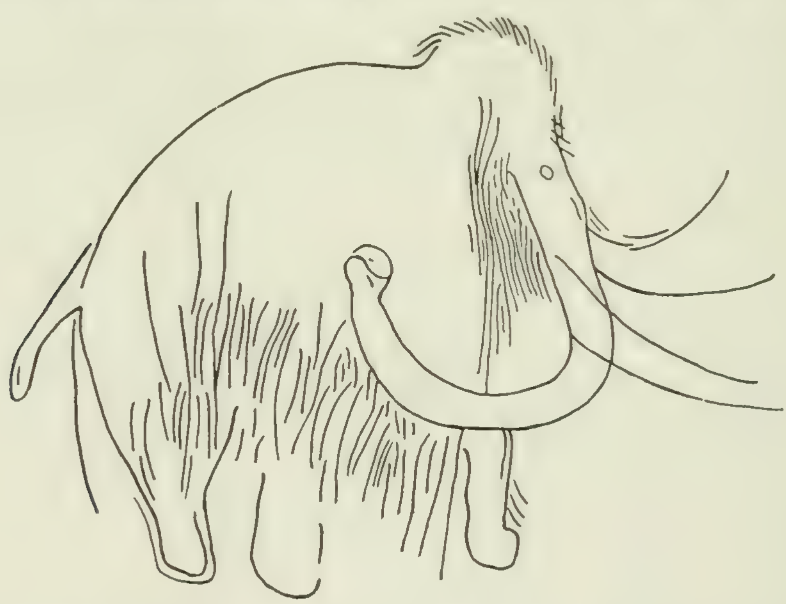


FIG. 19. REPRESENTATION OF THE WOOLLY ELEPHANT, DRAWN ON THE WALL OF THE CAVE OF COMBARELLES, LES EYZIES, FRANCE. Adapted from Capitan and Breuil.

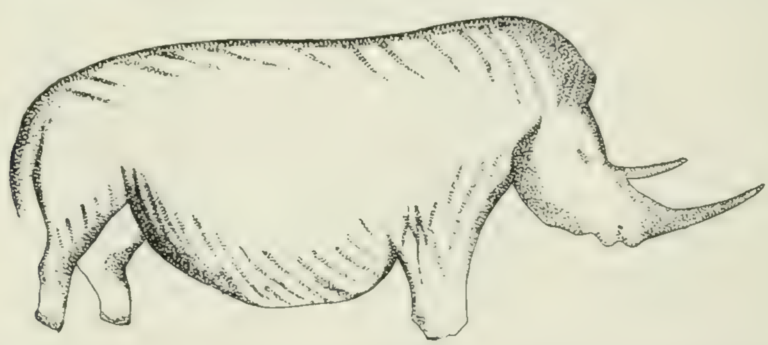


FIG. 20. PAINTING OF THE WOOLLY RHINOCEROS ON THE WALL OF THE CAVE OF FONT-DE-GAUME, LES EYZIES, FRANCE. Adapted from Capitan and Breuil.

FIG. 21. RESTORATION OF CRO-MAGNON MAN. Drawn by Frieda Lueddemann under the direction of the author.

surviving types are known principally from regions outside western Europe.

In physical development, and apparently in mentality, the Cro-Magnons approached closely the characteristics of modern man. This race represents in western Europe the beginning of modern life taking its origin in ancient times. The Neanderthals go far in physical characters, in mentality, and in environmental setting to bridge the gap between modern man and the earliest humans. The Cro-Magnons show us that even the modern cast of physical development is rooted deeply in the remoteness of an early geologic day.

SIGNIFICANCE OF DATA BEARING UPON THE PROBLEM OF HUMAN ORIGIN

Passing in review the stages in evolution of man, it is desirable to note once more the evidence of geological succession of the four human types already discussed, and with this to state that all four were present on the earth before the beginning of the present period. The proof of their antiquity seems especially striking when we consider that between the time of appearance of the third or Neanderthal type and the present day events of great geological and biological significance profoundly changed the face of nature, and that after the Neanderthals had become established in this region a period of fifty thousand to two hundred thousand years probably elapsed before the modern races became dominant.

It should be noted again that remains of the later stages, including Neanderthal, although apparently absent from the New World, seem widely distributed over Europe, Asia, and Africa. The first two stages, represented by *Pithecanthropus* and Heidelberg man, are known by single occurrences, and the one generally assumed to be the earlier is situated in a region known to be an area of evolution of the anthropoid group.

We have also seen that the series shows us, in passing backward through it, a reduction in brain capacity, increase in the prominence of the face, and a general taking on of anthropoid characters, until the earliest form is recognized as unquestionably of all human types the one standing nearest to the apes, and yet apparently distinguished from anthropoids by its specialized human limbs.

While the evidence is incomplete, the record as it stands agrees down to extraordinary detail with the expectation which one might have of early human history based upon the view that man, while a derivative of the anthropoid group, is now widely separated from all simian types, and has presumably required long ages in which to reach his present stage of differentiation away from the primitive stock.

The earliest occurrences are at the geographic point where we would expect to find them. The earliest types represent approximately the stages of evolution that the paleontologist would anticipate discovering in the strata from which they have been recovered. The later history shows a gradual modification at a rate corresponding in general to that seen in history of other groups of mammals. We note also that the family seems to spread itself gradually over the world, and as nearly as we can determine, with this wider distribution there begins the differentiation into distinct types or species characteristic of geographic provinces.

In a word, human history, so far as the development of physical or biological man is concerned, indicates that our origin is comparable to that of other organic groups, and that we are apparently an outgrowth from the mammal world subject to the same laws of evolution and differentiation as are expressed in myriads of other organic types. The existing races of man represent the morphological and geographical expression of this evolutionary history. Their characteristics are clearly the result of hundreds of thousands of years of differentiation. The stamp that is put upon each type is the product of extraordinarily complicated influences in which inheritance and environment are essential elements. They are not fleeting impressions, but have significance comparable to that definiteness in organic type which leads us to expect the rose to beget roses, and lions to be the offspring of lions.

As was noted in the introduction to the first lecture, students of biological aspects of the human problem have recently called particular attention to the importance of race as weighing definitely in consideration of many world problems, along with the factors based upon differentiation of peoples according to linguistic stocks, ethnologic relationships, and social organization. This is not interpreted to mean that great significance does not attach to the group influence in peoples organized according to ethnologic characters, or by reason of the effect of language, or through many other causes. It does mean that factors of fundamental significance, resting upon basal characteristics of human nature, brought out in our long history, and represented now in race, have perhaps received less consideration than is their due. It means not only that a clear view of the human situation must present a picture showing the common generalized characters represented in practically all human types and individuals, but that with these we must see also the length and breadth, the height and depth of human differences. Unless this view is taken we shall fall short of the interpretation of humanity needed in order to give to every group, as well as to every individual, that full freedom to develop *its own peculiar talent,* and to grow into the fullest usefulness which we assume to be the natural right of all.

And finally, the whole trend of history within the chapter just read from ancient records exhibits without question a definite progressive movement of the human type. This is expressed in physical capacity for greater breadth of comprehension, and in wider range of activity and occupation given by coordination of the brain and hand as also of the brain and tongue. Man of the present day may read his story back to that early stage in which he first sees himself distinguished from the beast. He sees the beast made to a man-like beast and then a man. Perhaps to you the student of this ancient life has seemed to look upon a passing scene which might well have been left unknown—and yet to those who read what he who runs may see, the present world is brighter for the view—the future built upon the upward striving of the past must see the best there is in life at length prevail.

OCCUPATIONAL THERAPY IN TUBERCULOSIS[1]

A Critical Retrospect upon the Program of Physical Reconstruction as developed in the Military Hospitals for Tuberculosis

By FRANK A. WAUGH

CAPTAIN, SANITARY CORPS

THE reconstruction of disabled soldiers is something new. It had never been tried before the great war on any appreciable scale. Nevertheless all the leading nations in this war undertook extensive and systematic reconstruction almost from the start. Germany, France and England began the work promptly, and on a large scale. The success of their efforts was sufficiently plain, so that the United States coming later into the struggle, felt constrained to undertake something along similar lines.

There was some uncertainty for a time as to how and under what direction this work should be organized. The plan eventually adopted was for the preliminary work of the hospital period to be done by the Surgeon General's Office, while the more extended work of vocational retraining was deferred until after discharge from the hospital and the Army, and was placed in the hands of the Federal Board for Vocational Education.

A Division of Physical Reconstruction, with Colonel Frank Billings at its head, was therefore organized within the Surgeon General's Office, and definite work began early in 1918. One general hospital after another was manned and equipped, and finally the work, having proved its value, was extended to several base hospitals. The first of the tuberculosis hospitals to be regularly organized for this work was No. 16. Lieutenant-Colonel Alexius M. Forster, Comanding Officer, an experienced sanitarium man, had begun certain work along reconstruction lines, especially gardening, early in the spring of 1918. In July, Captain Frank A. Waugh arrived to take up the organization of a larger reconstruction service under direction of the Division of Physical Reconstruction in the Surgeon General's Office. For the next few months the reconstruction program

[1] Published under authority of the Surgeon-General, United States Army.

was expanded, adapted and readapted to varying needs as fast as experience showed the way and equipment could be found. Other Army hospitals handling tuberculosis were later organized for reconstruction work, including No. 8 at Otisville, New York; No. 17 at Markleton, Pennsylvania; No. 19 at Oteen, North Carolina; No. 21 at Denver, Colorado; Fort Bayard, New Mexico; and Whipple Barracks, Arizona.

It is the purpose of the present report to review, summarize, and criticize the work thus far done under the reconstruction program in the tuberculosis hospitals. It seems highly desirable to make a full record of this large and interesting experiment and to determine as accurately as possible just what has been accomplished, to know what parts of the program have proved successful and in what degree, as well as what items have failed and in what degree. This detailed criticism is all the more needful because of the fact that civil sanitoria for tuberculosis are particularly anxious to profit by the experiments made in the Army hospitals. The present discussion is based mainly upon the experience accumulated at General Hospital No. 16; but Hospital No. 8 and No. 19 were also visited (as well as several other Army hospitals not specializing in tuberculosis), and considerable help has been secured through correspondence with officers doing reconstruction work in Denver and Fort Bayard.

Specific Purposes

Several quite distinct motives have been influential in the development of the reconstruction program. These have not all worked together, but have operated differently at different times. Any fair understanding of the work must be based upon a clear conception of these objectives. Those which appear to have been the most influential may be summarized as follows:

1. *Return of Men to Military Duty.*—During the progress of the war this motive stood above all others. In Germany and France, particularly, special effort was made to redevelop for military service the largest possible proportion of disabled men. In American hospitals likewise the salvage of fighting men was earnestly sought. Much of the reconstruction work done prior to the armistice was directed to the training of men for further military or semi-military service. Instruction in the automobile shops, for example, prepared men for the Motor Transport Corps, and training in telegraphy was directed to the preparation of men for the Signal Corps.

2. *Vocational Reeducation.*—At the outset of the work in the United States probably the leading thought was the voca-

BEDSIDE WORK IN AN OPEN WARD. Bead-weaving—very popular and remunerative.

tional rehabilitation of disabled men. It was conceived that many soldiers would be so injured, especially by the loss of limbs or of sight, as to be incapacitated for their previous employments, and their retraining for new vocations was considered a prime duty of the government. Two important observations may now be made with reference to this idea: First the number of men requiring replacement in new vocations proved to be very much smaller than anticipated; Second, such vocational retraining, when necessary, can be more efficiently given after discharge from the hospital. In the United States the work of the Reconstruction Service of the Surgeon General's Office divides naturally from that of the Federal Board for Vocational Education precisely on these lines—a division which now seems wholly sound and sensible.

3. *Functional Restoration.*—Historically this was one of the earliest and strongest motives behind the program of physical reconstruction. In orthopedic practice it obviously plays a major rôle. In the treatment of tuberculosis, however, functional restoration is of such minor importance as hardly to be considered a direct objective at all. However the functional test which comes toward the end of the treatment period is in some sense restorative.

4. *Graduated Exercise.*—Perhaps the nearest approach to functional restoration in the tuberculosis program is found in the application of graduated exercise as a therapeutic measure. The therapeutic value of graduated exercise seems to be still a very much debated point among medical men. The case ob-

viously can not be reviewed here; but we may say briefly that, wherever and to whatever extent graduated exercise is brought into play, it fits immediately in to the general program of reconstruction.

5. *Functional Test.*—Many medical men who do not believe in graduated exercise as a form of therapy applicable to any stage of the tuberculosis treatment would nevertheless favor a functional test or try-out for cases apparently fully arrested, this test to be carefully given under medical supervision before the patient is finally returned to full military or economic duty. This test would take the form of graduated labor increased from day to day, as indicated, up to the point of a full day's work. Such a test also becomes a part of the reconstruction program.

6. *General Therapy.*—It should not require argument to show that the various activities grouped under the rather loose term of physical reconstruction are capable of assisting in the cure of patients in many indirect ways. As regards the treatment of tuberculosis, a special point may be made of the reconstruction contribution to the rest cure. Rest in bed and later in chairs in the open air constitutes the standard treatment; at least it is the one feature to which constant attention is required. Now it has been amply demonstrated that for convalescing

Busy hours on an open-air ward. Reconstruction Aide in center; Nurse in background.

MAKING BASKETS AND TOYS ON THE OPEN PORCH IN THE SUN.

(non-febrile) bed cases and for all porch-chair cases the various forms of occupational therapy give more practical help toward the enforcement of the rest program than anything yet devised.

7. *Psychotherapy.*—Eminent tuberculosis specialists have laid much stress upon the mental attitude of the patient as a leading factor in treatment. While the value of this factor will doubtless be estimated differently by different men, all are likely to assign some importance to it. Experience shows that nothing does more than congenial occupation toward establishing an orderly state of mind, a healthy equanimity, an efficient self-control and a hopeful outlook toward the future. Results at this point have been so emphatic as hardly to leave any room for question.

8. *Morale.*—There is to be considered further the question of social psychology or the morale of the whole community. In the Army hospitals morale has been a critical factor, and it is certain to play some part in every sanitorium or colony. And we may say without hesitation that well-directed occupation for the hands and minds of patients does much to maintain morale.

9. *General Education.*—In the programs devised for the Army hospitals, general education early became a leading feature. The principal reasons for this were three: (*a*) The occupation of the patient's mind with interesting studies is fre-

quently the simplest form of occupational therapy; (*b*) The extraordinary and unexpected deficiencies in general education revealed in the Army made it seem a public duty to seize every opportunity for improvement; (*c*) Especially the illiterate element, which reached alarming figures, seemed to call for heroic measures of correction. Beyond these cases lay a certain number of men of better education who were glad to take advanced studies in commercial, scientific or semi-professional lines. The work in general education therefore developed to considerable proportions in the Army hospitals.

10. *Americanization.*—The alien soldiers, of whom there were vast numbers, presented a most serious special problem. Some of these were wholly illiterate, others could read their native languages but could not read English, practically all of them were very imperfectly schooled in elementary branches and dangerously ignorant of American institutions. It could hardly be denied that the government of the United States owed a special duty toward these men, and had a special need to protect itself by the Americanization of all such men to the utmost. A carefully planned and intensive effort was made therefore toward this end.

THE RECONSTRUCTION STAFF

In each of the general and base hospitals designated for the

HANDCRAFTS FOR BED PATIENT.

TELEGRAPH SCHOOL ON AN OPEN-AIR WARD.

reconstruction work a special staff was organized under direction of the Division of Physical Reconstruction. The staff was made up of four classes:

(*a*) Commissioned officers (those specially selected for this work being commissioned in the Sanitary Corps).

(*b*) Enlisted men, Medical Corps, specially chosen for educational or technical qualifications and taken by voluntary induction from deferred draft classifications. (A large proportion of these men were eventually given a noncom status).

(*c*) Reconstruction Aides, women specially trained in crafts or as teachers, and having a rather anomalous status somewhere between that of an Army nurse and a civil employee.

(*d*) Civil employees, both men and women, used in a great variety of duties.

METHODS EMPLOYED

In pursuit of the various objectives already set forth a great variety of expedients were adopted. Many methods were tried, with varying success. A review of the principal experiments seems necessary at this point.

1. *Vocational Teaching* in very mild forms was attempted at General Hospital No. 16 in gardening, poultry culture, telegraphy, typewriting, woodworking and automobile mechanics. For this work the personnel was good, the physical equipment meager.

2. *The General Schools.*—Small groups, mostly placed on wards and porches, were organized for instruction in general subjects, such as reading, writing, arithmetic, history, bookkeeping, drawing, French, etc. The instructors in these schools were of rather extraordinary caliber.

3. *Americanization School.*—A special school was organized to assist in the Americanization of foreign soldiers and particularly to secure the actual naturalization of every fit alien. This work was facilitated by special act of Congress. At No. 16 the Chief of the Reconstruction Service was also made Chief Naturalization Officer, thus coordinating the two undertakings. First of all every effort was made to teach every alien soldier to read and write the English language. All these men were then taken into a class in civics which met daily with a particularly competent instructor. The central feature of these daily meetings was open discussion of phases of government in which the patients themselves had had experience, *e. g.*, the post office and what it does, the policeman and his duties, the health department, the Army draft, the American school system, etc. The purpose of this instruction was to lead the men to see what American institutions are like, how they are man-

AUTOMOBILE SHOP—THE WORK CONDUCTED OUT OF DOORS IN THE SUNLIGHT.

A Greek pupil; illiterate, learned to read and write and became an American citizen.

aged and what is the real spirit of American government behind them. Finally these men were examined by a special agent of the Naturalization Bureau, were taken to the Federal Court by their instructors and given the papers which made them full-fledged American citizens.

4. *Individual Instruction.*—A considerable number of patients who could not, for one reason or another, come into these school groups were given daily instruction on their home wards by enlisted men or reconstruction aides. This work was reasonably efficient.

5. *Crafts Teaching.*—As the reconstruction program developed the largest single enterprise was the teaching and supervision of handcrafts on the wards. This work was wholly in the hands of reconstruction aides. The most popular crafts were hand weaving (colonial mats), rake knitting, bead weaving, leather working, basketry, manufacture of wooden toys, wood carving, simple metal working.

6. *Hospital Service.*—A certain proportion of patients are judged by their ward surgeons to be able to perform various necessary duties about the hospital, such as sweeping floors, helping in the kitchen, etc. Work of this sort has been assigned on prescription and recorded as a part of the reconstruction

program. When properly supervised it can be readily fitted into a scheme of graduated exercise.

7. *Military Drill.*—While the war was still in progress and the effort to return men to military service was still strong, a "Reconstruction Detachment" was organized at No. 16 into which were brought all men approaching recovery and destined soon to be returned to duty. Such men were given daily military drills, were present at retreat, etc. This routine was continued in a slightly modified form after the signing of the armistice.

8. *Graduated Walks.*—At some of the tuberculosis hospitals, notably at No. 8, extended use was made of graduated walks as a part of the reconstruction program. To a less extent this feature was developed at No. 16.

9. *Recreation.*—Athletic games are capable of contributing very largely to the restoration of physical function in cases where ordinary muscular functions are impaired. Thus in orthopedic hospitals the extensive development of athletic sports was natural. Such forms of recreation may also assist materially in keeping up morale. In the treatment of tuberculosis, however, active games have to be prohibited; but mild

A CITIZENSHIP CLASS. These alien soldiers all received their naturalization papers.

inactive diversions and games upon the wards are encouraged as a morale measure. For reasons of morale also the Reconstruction Service cooperated at all times with the various welfare agencies in a general provision of recreation for the post.

10. *Social Service.*—On March 6, 1919, the Surgeon General's Office sent to this hospital a special reconstruction aide designated for "medical social service." The field of her operations was most problematic, but the incumbent proved to be a well-trained and tactful woman who made herself distinctly useful in many ways. In general her duties were to collect personal histories of all patients as required on the Surgeon General's Office Form 58, to put patients in touch with the facilities of the Reconstruction Service, to see that every case of need of every sort was passed to the appropriate official or welfare agency, to follow each patient through the hospital and to see that his case was cleared up at all points when he left.

Criticism of Results

Having outlined the purpose of the reconstruction work and the methods adopted for reaching those objectives, it is now possible to make an appraisal of results.

1. *Return of Men to Military Duty.*—The work had not gone far enough prior to the signing of the armistice to have given definite results in the return of many tuberculous men to military service. It is obvious that such returns would necessarily be slow and comparatively few, and that the majority of the men returned would be fit only for limited service. Yet there was considerable promise of results within these limits.

2. *Vocational re-education,* as has already been pointed out, has proved to be generally impracticable under hospital conditions, and the burden of this responsibility has been taken over by the Federal Board for Vocational Education. Experience seems to indicate that a few cases in civil sanitoria may be found where a change of occupation seems advisable and in which the beginnings of vocational retraining can be made during the sanitarium period. Inasmuch as the cure of tuberculosis frequently involves the adoption of an entirely new plan of life, with all its psychological readjustments, and since vocation must bulk large in the adjustment of most men, it is obviously desirable to meet these problems as a part of the treatment and during the period of sanitarium reconstruction.

3. *Graduated Exercise.*—Avoiding still any argument as to the therapeutic value of graduated exercise, the possibilities of auto-intoxication, and all that endless debate, we may reiterate the statement that such exercise is perfectly feasible as a part

of the reconstruction program. However if it is to have any practical application it must have much more constant medical supervision than could be given to it in any of the military hospitals. This supervision must gauge the whole daily sum of exercise for each patient, not merely the relatively light work of an hour in the garden. This criticism plainly applies with equal force to the prescription of graduated walks. Such regular walking exercises may possibly be of considerable value to tuberculosis patients, but not unless they are supervised with great care.

4. *General Education.*—The general teaching given in the reconstruction schools was apparently of much practical value. Indeed it is clear that more of this work should have been done. Many patients who sorely needed help missed the opportunity. Possibly more compulsion or greater tact in handling these patients would have accomplished more. The work was most needed in the most elementary subjects; but much more might have been done to the general profit in commercial subjects, particularly typewriting and simple bookkeeping. The work succeeded best when given to small groups or to individuals upon the ward porches.

5. *Americanization.*—The work for the Americanization of alien soldiers has been one of the most fascinating and inspiring undertakings in the whole reconstruction enterprise. Its value can not be doubted. It has met with distinct success. While it has been peculiarly appropriate to the Army, it has such a general social value that it may seem almost indispensable in future tuberculosis work. Tuberculosis in our country is likely to be always partly a problem of the foreign population, of un-Americanized, uneducated, ill-paid social groups; so that whatever may be done to assist in general education and in Americanization cuts toward the very root of the disease.

6. *Handcrafts.*—The striking success of the handcrafts in all the tuberculosis hospitals makes it necessary to consider this branch of the work with some detail. First of all it must be seen that the success of the work was due in considerable part to the personal attractions of the reconstruction aides. This is offered as a cool scientific statement without any implications. The women secured for this service during the war period were nothing less than remarkable in their high character, their wholesome behavior and their inspiring personality. In this work personality counts very heavily.

But the character of the work itself makes it highly effectual to the purposes in view. It is interesting; it occupies the hands and mind; it is not tiring; it can be taken up or laid aside at will; periods of work alternate pleasantly with periods of relaxation; the finished product has demonstrable value. It must be recognized as a fact that the great majority of patients are not capable of any intense of prolonged mental attention. The handcrafts, however, reach their minds through their fingers, the shortest and surest route.

The educational value of these crafts has not been sufficiently recognized. Education is too generally regarded as a wholly mental process. This is far from true, yet if it were the literal fact, the handcrafts might still be the most effective means of arousing mental activity. Work upon a bead-loom, for example, requires a certain concentration of attention, and control of attention is one of the foundations of all education. It requires further a close coordination of the eye, of delicate muscular movement and of mental direction. This cooperation of mind and body is in itself education in one of its highest and best forms.

Moreover the pupil in handcrafts learns something of design and of honest construction. Both these items are of serious value to every hand worker whether he be carpenter, tinsmith, weaver, tool-maker, or farmer. It is a great defect of modern society that it depends too much on machinery. Everything we touch is machine-made. The common laborer in particular hardly ever sees or touches anything but machine-made objects. He begins life in a machine-made go-cart, eats canned food from a machine-made table with a stamped steel knife, fork and spoon, dies in the hospital in a machine-made bed, is buried in a machine-made coffin and marked with a machine-made tombstone. When such a man once makes with his own hands a good basket or leather pocketbook he begins to realize the value of honest craftsmanship—the place of personal responsibility in the day's labor. This is a most fundamental element in human psychology now largely lost in a mechanical world where objects are made by machines, not by men. The men only feed the machines and are themselves controlled by another social machine called a labor union.

Still further, though less important, it must be pointed out that the objects made by the patients taking handcrafts have an immediate commercial value. They are readily saleable and at good prices. The objection sometimes raised against the work of tuberculosis patients was conspicuously absent from our experience at No. 16. The patient who turns out a product which sells for real money experiences a stiffening of morale which is of the utmost value. No matter how discouraged he may have been he can no longer feel himself completely down and out.

This feature of the work, the sale of products of occupational therapy, demands careful handling, but it is worth all the trouble required.

7. *Hospital Service.*—Experience at Hospital No. 16, supported by the experience of others, shows that hospital service is a very difficult form of exercise to administer. The difficulties in fact are so great as to make the effort inexpedient except in a minority of cases. It seems probable that in civil hospitals where simpler relations obtain amongst patients and personnel more can be expected. Especially if a cash value can be placed on the service of the patient and this amount subtracted from fees which the patient must pay, or some other arrangement can be made so that he feels he is being fairly remunerated for his work, reasonably good results may be expected. This form of reconstruction work, however, is the most difficult of all to manage and the least effective for all purposes, so that we can hardly feel that those sanitaria which have made it the leading feature of their reconstruction programs have fairly broached the possibilities in this field.

8. *Recreation.*—While athletic sports are hardly admissible to a program of tuberculosis therapy, other forms of recreation are highly desirable. In every hospital, sanitarium or convalescent colony adequate provision should be made of wholesome recreative recreation. This matter is of such importance that it must not be left to chance. The recreation should be planned, directed, carefully supervised and coordinated with all the other therapeutic measures which we are grouping here under the rather loose general term of reconstruction. In the military hospitals these recreation activities have been divided amongst several volunteer welfare organizations, an arrangement obviously impracticable under other circumstances.

9. *Welfare Work.*—Inevitably a certain amount of welfare work or social service was done by the Reconstruction Service at No. 16. The more definite undertakings of this sort were made at the hands of the medical social service aide sent from Washington for that purpose. The great bulk of all such work however was done by the Red Cross, the Y. M. C. A., and the K. of C., not forgetting the official chaplains. A most considerable amount of such work has to be done at every civil hospital. Our experience shows that it can be effectively administered as a part of the reconstruction program and indicates pretty definitely that this is the best way in which to direct it.

Summary of Results

This experiment in the application of reconstruction ideas to the tuberculosis hospitals of the military group covered something over one year. During that time great changes occurred, not only in external conditions but in our intellectual conceptions of the purposes and methods. These changes have followed one another with bewildering rapidity. There was no leisure for study, reflection and generalization. These experiences remain yet largely undigested. There are many observations which still seem to contradict one another. Under such circumstances any statement of conclusions must be offered with great care. However a few points seem to be sufficiently clear to bear statement.

1. The reconstruction program has definite value in the tuberculosis hospitals. Every one seems to agree to that. Its chief utility lies in the assistance which it gives to the rest cure and the favorable mental attitude which it induces in the patient.

2. The work done in lines of general education and Americanization has also had considerable value.

3. The most successful feature of the program has been the occupational therapy or crafts work on the wards.

4. To make the work as successful as it should be, strict medical supervision is necessary. As a matter of administration, however, this supervision may be largely delegated to reconstruction officers as was done at General Hospital No. 8.

5. The experiment has been valuable, has probably been worth its cost, and much of the experience gained can be passed along to civil institutions.

The Future

Indeed this look into the future is what chiefly justifies the whole experiment. Tuberculosis we have always with us, and the war against it promises to be a much longer affair than the little flurry with the Central Powers. The treatment of tuberculosis in sanitoria and colonies of various sorts seems likely to be increasingly important, and in all such circumstances some form of reconstruction ought to be utilized. What does the Army experiment suggest for adoption into the peace-time warfare against tuberculosis?

1. In any given institution the work ought to begin on a small scale and be allowed to grow as its value is demonstrated and as means are available.

2. In a great majority of cases this beginning can best be

made with one first-class reconstruction aide, who must be a woman of experience, sound character and attractive personality.

3. Other sides, male and female, may be added as circumstances warrant. A male director should be appointed whenever the extent of the work justifies, and this director should be an educator rather than a physician. This distinction is important.

4. From the beginning there should be combined in this one service all the reconstruction functions of the hospital, *i. e.*, all social service, teaching, direction of crafts, supervision of recreation, etc., including everything now known either as reconstruction or welfare work.

5. In general the work should begin in the wards, and only after there are positive advantages in sight should there be developed any separate workshops or schools. Exception may be made for schools maintained primarily for the protection and observation of children of tuberculous parentage.

6. Hospital service as a form of reconstruction must be handled with great care, and should be presented in such a light as to seem to offer a direct financial advantage to the patient.

7. Gardening, poultry culture, bee-keeping and other light forms of agriculture may be used where good physical equipment and good teachers are available, but the medical supervision must be exceptionally careful.

8. The work must be at all times under the full control of the medical service, but best results may be expected if the details of all reconstruction activities are left entirely to the reconstruction workers. The value of experienced educational workers in this field seems to be fairly demonstrated.

9. Arrangements should be made in most hospitals for selling the products made by patients. These arrangements are important; they may also be difficult, and they should therefore be managed with considerable prudence.

The Cost

Every one who considers the introduction of reconstruction work into civil sanitaria must early face the question of cost.

To begin the work as recommended with one first class woman aide will cost approximately $1,500 a year for her salary. There should be a fund of about $500 for initial equipment. In the judgment of the writer it will be entirely feasible in most institutions to make the products of occupational therapy pay the cost of raw materials, probably something over, so that steady expenditures on this account need not be anticipated.

It may be estimated that each good reconstruction worker can care for from 50 to 100 patients. Indeed one single worker could do a world of good amongst 500 patients, but a ratio of 1:50 or 1:100 is safer.

If workshops or outdoor schools or other buildings must be provided they present another item of expense, but this item is so variable as to escape estimate.

Post-Sanitarium Applications

The spirit and methods of reconstruction furthermore seem capable of projection even beyond the sanitarium in the treatment of tuberculosis. It is well known among tuberculosis workers that one of the most critical periods in the cure comes at the point of discharge from the sanitarium. The patient passes abruptly from a regimen of rest (or comparative rest) to a full day's work, from the wholesome surroundings of the sanitarium to the old home, sometimes unsanitary to a degree, from constant medical supervision to no supervision at all. Worst of all he feels compelled to do what others do, whether that be hard lifting in the day's work or staying out late at a dance. The results are seen in a deplorable percentage of relapses.

It has seemed that much might be gained if this transition could be made more gradual. The one crucial point usually lies in light part-time work at which the patient can become partially self-supporting and in which he can progress safely to heavier labor and longer hours as he gains in strength. In short the problem is one of graduated exercises, of occupational readjustments, and follows logically upon the reconstruction work of the sanitarium period.

The solution which appeals to many minds as promising for trial lies in the provision of industrial colonies, institutions which would lie between the sanitarium and general industrial life. A very interesting study of this proposition has been published recently by Dr. H. A. Pattinson.[2] The present writer prepared an outline project running along similar lines which was considerably discussed at General Hospital No. 16 by the medical and reconstruction staffs. The outline is herewith reproduced as suggesting a further extension of reconstruction ideas to the everlasting fight against tuberculosis in civil life.

Reconstruction Town

Sketch Project for a Village devoted to the Care and Rehabilitation of Persons recovering from Tuberculosis

[2] Federal Board Vocational Education Bulletin, Series 6, No. 32, June, 1919.

1. *Purpose.*—Primarily to supply post-sanitarium care for persons recovering from tuberculosis, and to effect their full and permanent rehabilitation, physical, economic and social.

2. *General Scheme.*—To provide the facilities necessary to this purpose in a special village or villages. Preferably such centers will be created *de novo* in selected locations. The essential facilities would appear to be:

(*a*) A rather full and paternalistic control of industries, exercised perhaps by a director of industries.

(*b*) Adequate medical supervision, probably exercised through a public dispensary and clinic.

(*c*) An intelligent social service.

3. *Physical Setting.*—Such a colony should be located within reasonable distance of large centers of population yet outside the urban districts. The village should be designed by the best specialists in modern town-planning and industrial housing, and such plans should conform clearly to the special purposes to be served.

4. *Location.*—Sites for such colonies might be found within or upon the borders of the national and state forests. Certain advantages would derive from such location, in particular the following:

(*a*) Large tracts of suitable land are easily available.

(*b*) The surroundings would be wholesome, sanitary and attractive.

(*c*) The forests supply the foundation for permanent industries especially adapted to the needs of such a colony. This is a most important consideration.

(*d*) Necessary conditions of land tenure and administration would assist toward the somewhat paternalistic control essential to success.

5. *The Family Unit.*—Since this plan assumes the protracted—in many cases permanent—residence of convalescents, it must provide for their families. In fact an essential feature of the service contemplated is to transplant infected families to a new environment where the children may be protected.

6. *Economic Foundation.*—Industries should be of such a nature and managed in such a way as to provide graduated labor, under safe and wholesome conditions, to convalescents and recovered patients in all stages. Light occupational therapy could be given to chair patients or those still in their homes; light work in special shops for short periods to patients more fully recovered; full-time work to those capable of it. All would be under constant medical inspection. (The small wood-work-

ing industries seem particularly adapted to this end.) Obviously these industries must be organized and supervised with a view to the rehabilitation of men and women rather than to the exploitation of man power or of the forests.

7. *Other Employments.*—The economic ideal would be found in a completely autonomous and self-supporting community. Beside the basic industries there would be many correlative functions open to convalescents and to recovered persons. These would include laundry, garage, telegraph and telephone service, shop-keeping, road mending, etc. In particular should opportunity be available for small farming, truck growing, poultry keeping and other food-producing enterprises as a part of the community development.

8. *Social Engineering.*—It would be clearly necessary to provide schools, religious opportunities and specialized facilities for recreation. These should be directed by competent persons and definitely coordinated with the therapeutic and prophylactic control.

9. *Financial Support.*—Such a community might eventually become largely self-supporting. At its inception, however, considerable sums of money would be required. It would probably be necessary to look to private sources for these funds rather than to federal or state support.

10. *General Control.*—Might be exercised through a special board of trustees, through the National Tuberculosis Association, or in some similar way. Some form of self-government for the community should be devised compatible with the central control of essential features.

ACADEMIC UNREST AND COLLEGE CONTROL

By Professor J. J. STEVENSON
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GREAT unrest exists, for many reasons, in academic circles, but the most disturbing protests are against efforts to control expression of opinion by college professors, which are denounced as not merely infringements upon the right of free speech, but also as attacks upon "academic freedom," certain to bring about disaster in the near future. The general unrest may be regarded by some persons as manifestations of the growing unwillingness to endure restraint of any kind; yet one must not dismiss it as simply a phase of the anarchistic tendency in all classes of society; the matter is of vital importance; it involves complex problems, affecting the usefulness of our colleges and secondary schools.

A man, sole occupant of a far-off island, is untrammeled save by physical conditions; but in a community no such freedom can exist. Each man has rights, but, in exercising them, he must not interfere with the rights of other men. This law is recognized as obligatory especially upon men in responsible positions, who, in the nature of the case, may not do many things, which an ordinary citizen may do. They have consented to curtailment of freedom because they prefer honor or emolument. When a man becomes employee of any type, be he bank president or sorter of rags on a dump, he voluntarily deprives himself of rights that he may gain something more to be desired. This is equally true of professional men, since they, in some sense, are employees. They make the surrender without compulsion; no man is compelled to become clergyman, physician, teacher or lawyer. He is untrammeled in choice; the world is wide and he may gain a livelihood in any one of many directions.

But there have always been college teachers who refuse to concede that they have renounced the exercise of any personal rights; men, whose acts assert the conviction that a college appointment confers the right to be a free lance in discussions relating to morals, social matters, politics or religion. Yet no one has suggested that such appointment endows a man with omniscience or even with ordinary common sense. But colleges are under bonds, which must be kept in mind not only by the trustees, but also by all employees, from the president, down or up. Gifts, usually more or less conditional, have been received from donors and similar gifts are sought from others. The greater part of the older colleges were founded as denominational schools or in close relations with a group of religious bodies. The usefulness of a college is dependent on the good-will and confidence of the community, which is apt to be conservative in educational matters—for, however radical in opinion the ordinarily intelligent man may be, he rarely desires to have his children begin where he expects to end. As holders of trust funds and as responsible for training of youth, trustees of colleges are under obligations, which honorable men can not ignore—and those who seek appointment as college teachers should bear this in mind. Reference to such permanent obligations seems to give pain to some advocates of "academic freedom," as savoring of vulgar "commercialism" and as unworthy of consideration by dwellers in an intellectual atmosphere. But commonplace honesty ought to be at least as important in the conduct of college affairs as in ordinary life.

"Independent thinking" does not mean advance or originality in thought; it may be only erratic thinking. Opposition to prevailing opinions is no proof that the man is a "reformer"; his sincerity in independent thinking has nothing to do with the matter. He may be convinced that marriage is merely a survival of property rights; that a trade unionist, punished for dynamiting houses and imperiling lives, is a martyr in behalf of human rights; that ownership of land is positive proof of crime in the past or present; that the whole organization of society is based on injustice by the few; that the only hope for this world is overthrow of all conditions now regarded as normal; but this sincerity gives him no right to demand that the college retain him and pay a salary that he may conduct a propaganda, at its expense, inside or outside of the classroom.

But there are matters which too rarely are considered carefully. Colleges do not exist in order to petrify intellectual conditions, or to prevent increase of knowledge; no sane man would maintain that restrictions should be placed on investigation, for such procedure would be disastrous. A teacher, who is not a genuine investigator, becomes a mere lesson-hearer, a purveyor of second-hand opinions, as expressed in the text-book. To be efficient in the classroom, one must be a coherent thinker; but that mode of thinking becomes confirmed only after patient search for the truth, diligent comparison of arguments on both sides of the questions involved. This type of work should be done without consideration of possible results, as truth alone is the object sought. When the writer entered college, more than sixty years ago, the respectable community knew that scientific man and infidel were practically synonymous terms—astronomers alone being possible exceptions. But chemists, physicists, geologists and naturalists held close to their work; their discoveries came in quick succession and, in great part, were accepted as genuine. The world soon recognized that the prevalent conception respecting scientific men was born not of knowledge, but of prejudice, that it was merely an echo of the metaphysicist's dictum, that study of material things unfits a man for contemplation of spiritual things. This was the outcome of untiring, patient investigation, of which the results were published, with rare exceptions, in a judicial manner, without reference to misrepresentation by opponents. Such work must be encouraged not only in natural science, but also along other lines of study. There are problems in psychology, economics and sociology, which are perplexing to the last degree, as the facts are obtainable only with difficulty and the evidence is apparently conflicting. Here, however, the temptation to publish incomplete work is too great for men anxious for recognition by the reading part of the community. Startling hypotheses are apt to be published as if they were final results. Such hasty publication should be discouraged as emphatically as patient, judicial investigation should be encouraged. To determine the border line between investigation and mere compilation of so-called statistical facts is difficult—it is not easy to determine when veal becomes beef; but there must be a determining body.

Equally perplexing are questions relating to participation in political and religious discussions. The opinions now maintained by the writer are wholly different from those which he maintained twenty-five years ago, the change being due as much to actual experience as to wide observation. It is not wise for college professors to take active part in such discussions; their calling unfits them.

In the class room, they are regarded by students as practically infallible and, in time, they are apt to become convinced that the students are correct in their estimate. Too often the nature of their studies renders them self-centered and, except in a few departments, they are not brought into such contact with the business world as could satisfy them that they are not a superior race. This positiveness is only too manifest in the cases where intellectual force or the exigencies of conflicting elements have put them into prominent places, for there they exhibit a strange indifference to public opinion. It would be well if professors abstained from active participation in public affairs and devoted their energies to work in their special departments. But such limitations should apply equally to all members of the staff; the president should not be permitted to be Oliver Twist for one political party, unless a professor be permitted to be the Oliver Twist for an opposing party, if he so desire. The chief objection to prominence of this kind is that it is due to the prestige of the college and in very small part to the man's ability. The respectability of the college is capitalized to cover defects of the machine-managers. Usually, the innate sense of propriety determines well the extent to which one may go, but, certainly, there have been, as there will be, occasions when college authorities must decide whether or not they will permit expenditure of college funds to aid a man's efforts to gain prominence in church or in state.

It is well to note the strange tendency to ignore the fact that, speaking legally, all persons receiving salary from a corporation are employees. This assertion has been resented bitterly by some writers, who hold that college teachers are appointees, not employees, and that the corporation, having confirmed an appointment, has no authority to remove the appointee. If such were the condition, the college trustees would do well to seek the heirs of donors and to return the gifts, as the trusts can not be fulfilled. But the claim is without basis. The argument that the President of the United States appoints justices of the Supreme Court but can not remove them is not accurate. The President nominates, but the Senate confirms or rejects. The Senate is the appointing authority, and it is the jury before which an impeached judge is tried. Similarly in a college, a committee or the president nominates candidates, but the trustees appoint or reject. No other condition is possible, as financial agreements must be made.

A notion seems to prevail among teachers that peculiar sacredness is attached to their profession. This perhaps is of medieval origin, for in most of Europe, teaching was one of the many duties required of clericals. In this country, the older colleges began as preparatory schools for the Christian ministry and were in charge of ministers. Perhaps, the wretched salaries paid to clergymen and college teachers are due to medieval conceptions, for clericals in the dominant church were celibates, supposed to need little of this world's comfort. But there is nothing sacred about the profession of college teaching; no reason exists why an "appointment" should be so guarded as to render extremely difficult the removal of an incompetent or indifferent teacher. Professorships should not be havens of rest for the slothful or negligent. In other professions men must prove themselves competent or must fail.

While recognizing the right and the duty of trustees to remove slothful, incompetent or injurious professors, one must insist that there are cogent reasons why a certain degree of security must be assured to the professor; and these have been conceded in the better grade of colleges, so that one receiving a final appointment has a, so to say, civil service hold upon the position. Preparation is long and costly; the salary, at best, is meager; promotion is very slow; while a man's efficiency should increase as he grows older in the work. The honest worker must feel that, as long as he does his work faithfully, his position will be secure. The interests of colleges demand this security because the teaching staff is the essential portion; its members have been chosen to do the work for which the college exists. There have been comparatively few cases in which abrupt or unjust "removal for cause" has occurred, but, unfortunately, they are not unknown. Trustees are almost isolated from individual professors in our larger institutions and are liable to be influenced by opinions of an officer who, honest perhaps, is certainly human, and is not apt to love those who do not see eye to eye with him in matters of policy. Unquestionably, some recent events have led thoughtful men to feel that radical changes must be made, if proper working conditions are to continue.

The American college is a legal body authorized to conduct an educational work without pecuniary profit to the incorporators. The trustees are not expected to manage details of that work, though they are responsible for them as much as for the financial details. The corporation employs a number of supposedly qualified persons to care directly for the teaching, one being designated president. The college thus consists of trustees the faculty, with the students, who are raw material to be fashioned into finished product. A university differs from a college only in that it consists of several schools, each with its own faculty. All machinery necessary to effective working appears to be provided in this organization, but, naturally, some adjustments have to be made in most cases to secure smooth operation.

Originally, the trustees were intended to act as "nursing fathers," guarding the orthodoxy of the professors, who were dependent on the fees for salary; if any deficit came, the faculty had to look after it. As a rule the trustees had great respect for the professors and cultivated their acquaintance assiduously. In later years, the great increase in property and the greater broadening in scope of work, with consequent enlargement of faculties, have made it almost impossible to maintain the intimacy formerly existing between trustees and professors; one is justified in saying that in some of the larger universities, there are trustees who can not tell the names of the oldest professors in the several faculties. No work can be conducted properly amid such conditions—a close personal bond must exist between trustees and professors. The faculty should have general control of educational affairs and the trustees should have general control of financial affairs. But there is a borderland where the duties overlap; it is necessary that the trustees consent to changes in curriculum and methods and, at times, the faculty must be consulted in reference to expenditures and buildings.

The president is supposed to be a bond, as he is usually a trustee; but, unfortunately, instead of bridging the gap, he is apt to convert it into a wide chasm, over which he may fly in a private aeroplane. Action by trustees has placed in his hands control of many matters, which should be delegated by them to no one. The self-perpetuating character of the board, so generally existing, makes possible for a shrewd man to fill vacancies with persons of his own choosing. In far too many instances, the president was not selected because of fitness to have oversight of the educational work; he is no bond between trustees and faculties and, under present conditions, he can not become one; everything tends to make him autocratic, as though the college were his personal property.

Each faculty in a university should be represented on the board of trustees by its dean, *ex officio* and without vote. This officer should not be selected by the trustees, but should be elected by the faculty in secret ballot, that he may be truly representative. This, however, is not sufficient, a closer bond is essential. A joint committee of trustees and professors should be chosen by each board for each school, two trustees and two professors, with the president as chairman, *ex officio*. All matters affecting any school should be referred to its committee, and no action should be taken by the trustees until after a report from the committee has been presented. Such an arrangement would bring trustees and professors into definite relations, would prevent the former from becoming nominal and would increase the dignity of the office. Such committees exist in some universities, but they are not what they should be as, in most cases, the members are selected by the trustees, the faculty having no voice in the appointments.

These propositions are based on the assumption that trustees, president and professors are well qualified for their respective positions. Unfortunately, this assumption is not wholly correct. Reformation in college affairs must be begun by complete change in method of selecting men for appointment to the several offices. The writer desires to offer some suggestions.

The board of trustees is responsible not only for the financial affairs, but also for the teaching work, the latter being the business for which the corporation was formed. This combination of responsibilities calls for strong men, whose hearts are in the work. One might well imagine that a liberal proportion of professors should be in the board, as they understand the nature of the work, while their success in rearing families on small salaries proves no slight ability in finance. The writer knows of more than one instance, where a university was saved by the faculty, after a board of able lawyers, clergymen and business men had given up the attempt in despair. But this type of representation has never been tried in the United States, though it has been remarkably successful in Scotland. In this country the office of college trustee seems to be regarded generally as a post of honor not of responsibility. There may be no personal responsibility before the law, but for that reason the moral responsibility is greater. Eminence in professional life or success in business affairs is no evidence, in itself, of fitness; no more is possession of wealth or a reputation for generosity. Men chosen to trusteeship should be familiar with the nature and needs of college work and they should have time as well as will to serve the institution. No man with proper self-respect would consent to be a nominal trustee; he would not endeavor to shirk responsibility by transferring his duties to a president. Any trustee who has not time and inclination to do hard work should resign, that a proper man may have the place.

The office of college president, anomalous in many ways, was an outgrowth of rapid expansion after the Civil War. In earlier times, the president was the mouthpiece of the faculty, over which he presided. Now, however, he is the executive officer of the corporation, general manager of all operations, financial or otherwise and in many cases he is member of the trustees. The crying need of every college is money and more money for "expansion" and for buildings; and the president is expected to find this money, as well as to advertise the college, so that the number of students may be increased and the need for still more money may be emphasized. The condition is bad; the duties are unrelated and should not be assigned to one man. The college or university president should be concerned chiefly with educational affairs, an *ex officio* member of each faculty and a genuine bond between them all. He should be chosen because of proved fitness to superintend the general internal affairs of a college; because of known probity in speech and action; and he should be a teacher earnestly in sympathy with the teacher and his work. Happily, there have been, as there are still, some presidents of this type, who care less for "expansion" than for honest work. Securing of money should be the task of a special officer.

Trustees and their duties are important, but professors and their duties are more important. If the faculty be incompetent, the college can not do the work for which it was founded, even though the lists of students increase greatly. No shoe factory could claim public respect and confidence if it merely succeed in foisting on the community a great quantity of inferior shoes, labeled as the best. The type of output is the test; if it is to be good, the workmen must be good and honest.

To secure proper men the college positions must be inviting; but they are not inviting to strong men. There is little pecuniary inducement; a life of leanness is the prospect. Formerly there were inducements for men who cared less for money than for opportunity to devote their lives to research. For such men, the long vacation and the few hours of teaching were all-important. But vacation and "literary leisure" no longer exist for the younger men in our great universities or for the greater proportion of the older men in the others. Summer schools increase the total roll of students and the fees received by teachers help to meet payments for the necessaries of life. "Expansion" of course and multiplication of schools without multiplication of professors have increased the hours of teaching. Even in many of the larger institutions the hours of work are scattered throughout the day; too often, the intervening hours are occupied in committee work, for the machinery has become complicated. Vitality is sapped and little energy or will-power remains for genuine study. If a man persist in research, his associates may soon have opportunity to lament the untimely end of a promising investigator. Certainly, the old-time inducements no longer exist, and it is becoming increasingly difficult to secure able, ambitious young men as teachers. If present conditions continue, our colleges will soon cease to be nurseries of science and literature.

The board of trustees ought not to choose men to serve as professors; ordinarily, its members are not familiar with the requirements and know little about the duties which a teacher must perform. Under present conditions, the president of a college or university should not be authorized to make selections or to present nominations. He has no time to investigate the claims of candidates and, in too many cases, he is not competent. No one would suggest that he select professors in law, medicine or finance, yet he is thought competent to choose college professors in arts and science, because he had taken a college course somewhere and perhaps had taught during a year or two in a secondary school, to secure means for a course in a professional school. His ideal of college work and his conception of successful work frequently differ greatly from those of the genuine teacher.

The primary selection of candidates should be made by a committee of professors in allied departments, aided, if possible, by competent men outside of the college. This committee should select two candidates to be recommended to the joint committee on the school concerned, by which a special investigation should be made and a choice made for nomination and confirmation by the board of trustees. A complicated process, one may say, but an ounce of prevention is better than a pound of cure, even in college circles. It is all-important to avoid saddling a college with hasty injudicious or not just men. A modification would be necessary in selection of assistants and instructors, but in no case should the decision be left to the caprice of one man.

The suggestions are: close contact of trustees and professors is essential; where several schools exist, an intimate bond should unite the faculties; trustees and professors should be selected most carefully; the work in each department should be supervised and all should know that a college is not an asylum for the indifferent, incompetent or slothful; a just salary should be paid and the importance of opportunity for study should be recognized; zeal for increased number of students should be discouraged and quality, not quantity, of the output should be the aim.

PHILOSOPHY IN THE SERVICE OF SCIENCE

By Professor A. H. LLOYD

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PHILOSOPHY is often charged with being careless of science or even with being deliberately superior to science and anything scientific. Among scientists the very word philosophy may even be a word of offense. In the name of all that is right and true and lovely and of good report the devotee of science is warned that above all things he must not get philosophical. To quote the Scriptures—somewhat at a distance—he can not serve science and philosophy. Simply, philosophy is unscientific.

As to this charge Lord Byron has happened to speak wisely:[1]

> And after all what is a lie? 'T is but
> The truth in masquerade; and I defy
> Historians, heroes, lawyers, priests to put
> A fact without some leaven of a lie.

Philosophy is indeed unscientific; but also philosophy has long and faithfully been in the service of science. How long? Ever since science began. How faithfully? Let me not say, lest I seem to boast. Only, in a word as quaint as appropriate, philosophy has been true handmaid of science, serving her mistress well if not always apparently. Philosophy most certainly, being so loyal a servant, would not speak rudely or disrespectfully; but many another faithful maid has said of her mistress: "I just tell you, it 's me as has taught her how!" Philosophy's service of science, then, has not been exactly slavish or conventional; but it has been real and, as does happen even in service, it has been instructive.

Of course philosophy has served other disciplines besides science; theology, for example, as will be pointed out here in due time; but its service as handmaid of science, besides coming in an interesting historical sequence after that of theology, obviously relates to the subject of this present essay. Also, as it is finding expression at the present time, especially if the present be appreciated in the light of the historical approach, it has special significance for certain tendencies of the time. In her service of science, furthermore, philosophy proves every

[1] Don Juan, Canto xi, stanza 37.

century or two to have changed her mistress, leaving one science to go to another. Her fickleness, however, like her unconventional way, in no sense detracts from the interest and importance of the relationship. On the contrary, when understood, it throws light on the real nature and value of the service itself and also it provides any one, who can and will read it, a most absorbing story.

Now I can not set up any claim to being a good story-teller; but I shall make an attempt, trusting that my own interest will supply some inspiration. Before beginning, however, it seems wise that I say something of the general character of philosophy's service of any discipline. Thus this service is—how shall I put it?—wholly characteristic, of course; I suppose, like that of any handmaid with her own inevitable manner, brogue, accent, atmosphere. Being what she is, philosophy, however servile, must always be concerned, whether quietly or assertively, with the universe, not just with some special field or point of view. Generalization is her very life and purpose and, although it may be what makes her restless and unconventional, it is her opportunity for a vital service. True, the opportunity has great dangers and from these many have suffered; but opportunity always implies danger. Philosophy, again, must be speculative, even in a sense imaginative, inexact, poetic, not soberly literal, not formally dogmatic, as we say of theology, or empirical and positive, as we say of exact or would-be exact science. Her interest, too, must be vital and appreciative, not just "objective," not just descriptive and explanatory, not under constraint of too precise instruments and too accurate measurements; concerned, then, with values, not merely with facts. So the commands, the specific doctrines and precepts of her mistress, whoever this happen to be at the time, she takes and must take only as mediating symbols or—a better word—analogies in the sense even of metaphors. Especially must philosophy never commit the error, by no means uncommon among scientists, of actually or virtually taking useful standpoints and methods as literal indications of reality. No science is metaphysics. So true are the various things that have just been said that philosophy's service of a science is often transforming or transfiguring almost if not quite to the point of baffling recognition. Once upon a time, you know, just an ordinary maid went out in her mistress's clothes; was met on the street by the mistress herself, and was not discovered. Philosophy, while no ordinary maid, must still take liberties. Philosophically thinking the whole after the manner of any scientific part, be this doctrine, standpoint or method, may or indeed must lead to some violence. Facts and methods, valued for philosophy as for life, must undergo change. It is, after all, a poor service that does not make itself really felt!

But, to turn now to the story, the progress of Christendom does show philosophy in a most significant succession of positions of service. To begin with, as often chronicled, in the Middle Ages philosophy was handmaid of the Church or of dogmatic theology, *ancilla ecclesiæ.* In the seventeenth century or thereabouts began the service of science; first, during the seventeenth and eighteenth centuries, of mechanics and mathematics; then, in the nineteenth, of biology; and, more recently, of anthropology and psychology. Theologism, mathematicalism or mechanicalism, biologism and psychologism: in such terms, very general indeed, may one tell the history of the philosophy of Christendom.

And this history, as it is true, can not but have interest. Thus, it implies what many a scientist would readily and too cheerfully overlook, that theology has a real place in the growth of the intellectual life, being even a cry in the wilderness before the coming of science, and that each of those sciences, at least for philosophy, has or has had its own special day and generation. It is true that for those who must regard science and theology as essentially opposed and incongruous any suggestion of historical sequence and continuity is bound to cause at least wonder, if not something stronger! Many, too, may wish to protest against a view that arranges important sciences in a temporal order and so seems to question their equality and their essential contemporaneousness. No science cares in these days to be treated as a "has-been." But, whatever the wonder or the protest, theology has had its real place and, although herein is no ground for denial of contemporaneousness, the different sciences do fall into an historical order; the earlier, as I would submit, being now in varying degrees of only mediate interest and value, the latest of immediate interest and value, to life and philosophy.

Furthermore, philosophy being life's reaction, intellectual and volitional, to the world as experienced and as immediately interesting at any given time, in our history with its sequence: theologism, mechanicalism and the rest, we can see that upon each change in the ism man is less aloof from the natural world, more at home in this world, more intimate with its life. In short—and just here is a matter of special interest—that sequence reveals a centuries-long process of civilization—synonymous with naturalization?—or say biologically of adaptation to environment. If the phrase, adaptation to environment, be misleading or out of date in its point of view, then any one who prefers may substitute sympathetic or functional change in man and his world or, again, progressive variation in their manner of interaction or in the mediation of their essential and persistent relationship. In history as in biology, unless I be very much mistaken, organism and environment have evolved or grown together. Still, for simplicity's sake, we may here keep the admittedly one-sided point of view of the more conventional phrase, adaptation to environment.

After a fashion every one knows how our western civilization, how Christendom, at first shut up in an unworldly—at least in theory and proclamation unworldly—institution, gradually came to earth; at first with much reserve and fear, with little real candor, but eventually with open enthusiasm and appreciation. In the twelfth to sixteenth century, notably in the period of the Renaissance, the great institution, the Europe-ruling Roman Catholic Church, turned creatively artistic, seeking so to humanize and acclimatize or naturalize all the various factors and practises, the ways and the offices, the doctrines and the imagery, of its life and organization. However selfishly and defensively, it made real appeal from the spiritual to the sensuous and physical, from its own separate world to the "external" material world, from the unnatural or supernatural to the natural, evincing an interest in rhetoric as well as in dogma and logic, in man's sensitively living body as well as in his immortal soul, in the vernacular languages as well as in the dead and other-worldly Latin and at least for first resort in the subtleties of cunning and artful diplomacy in place of compulsion by holy mandate or—the worldly counterpart of this—brute force; and, while the Church turning thus to an artistic expression of its life doubtless did have at first more of intrigue and indirection in it than of candor and appreciation, the step which Christian civilization took at that time, so to speak, from Heaven towards earth, from its institutional aloofness towards nature, was very real and very important as a first positive step both towards an eventual adaptation and towards natural science. Appearing as compromise and intrigue, it nevertheless was in service of an honest purpose. In clear evidence of something more than mere defense and selfish intrigue the Church of the time had its liberals as well as its conservatives and in good time came the Reformation and the great schism which brought a distinct and positive candor towards the human and natural. Followed the great era of objective science, of democracy, industrialism, machinery, in a word of social, moral and political as well as intellectual naturalism in place of the earlier aloofness and unnaturalism.

But now, while after a fashion every one does know this story and in it can see man slowly but surely finding himself in nature, adapting himself to his environment, there are aspects of the process, as so recounted, and particular stages of it, which need special consideration.

In the first place, how rose at all that unworldly institution in which so long civilization dwelt aloof? Historically, whatever be any one's religious or theological accounting for it, it rose as a device of safe retirement, an ark some very properly have called it, when with the collapse of the ancient civilizations, notably of Rome, the great floods came. As those floods rose, civilization withdrew into itself, gathering its acquired ways and protective covering about it. Did not the great father St. Augustine proclaim his "City of God," the Church, and did not the Bishop of Rome come into his papal power, as Rome approached and finally reached her fall? As a device of adaptation the Church doubtless seems hopelessly negative, adaptive through withdrawal rather than through direct action and even suggesting one of those strategical retreats of which we were hearing so often a year or two ago; but, negative or not, it proved not only a wonderfully effective device, strategically wise for its day and generation, but also—and this I would now specially stress—a most valuable preparation for the more aggressive and openly practical enterprises that came later. The very barbarians who overwhelmed Rome it took captive. It assimilated to itself all of western Europe and by its rites and offices, its education in all departments of life, its splendid organization, it really made our modern rationalistic or scientific naturalism the true lineal descendant of its institutional supernaturalism, possible. Very much as alchemy developed into chemistry or astrology into astronomy, so its régime, moral and intellectual, strangely enough only the more rigorous because of the magic or the supernaturalism upon which it counted, eventually made possible the larger and only more general rationalism and mechanicalism which was inaugurated practically with such achievements as the successful navigation of the open sea and theoretically with the successful use—as for example by Galileo—of the mathematical equation in explanation of natural phenomena.

Few have seemed really to appreciate that, practically or theoretically, the change from a supernaturalistic, militaristic institution to a mechanical nature was only the outcome of a generalization by which the spirit of the institution sought and found itself in the world as a whole. Such, however, appears to have been the fact and this fact in a peculiarly significant way reveals the adaptation-value of the great medieval institution besides showing the active and serviceable presence of philosophy and generalization. It shows, too, that the important progress made in the eighteenth century, when the naturalistic rationalism succeeded the old order, was really evolutional rather than merely revolutional in character.

That the modern era got its schooling in the Middle Ages, Protestantism from Catholicism, democracy from monarchy, industrialism from militarism, the mechanic from the soldier, rationalism from apologetics, mechanicalism from dogmatic institutionalism, inductive science from deductive, mathematics from positive legalism, even moral independence and conscience from the Church and its confessional, needs to be clearly recognized and appreciated. The pupil, moreover, learned his lesson well. But, not to prolong this chapter of my story, the new life did spring out of the old and an age of institutionalism gave place to an age of rationalism. Machinery, authority, causation all turned universal; creationalism yielded to a general mechanicalism; theology opened into science.

And with the coming of the era of science, institutional ritual and law being subordinated to natural law, our story of Christendom's progressive adaptation to environment gets somewhat easier. Certainly any one can appreciate the progress in the change from mathematics and mechanics to biology or in that from biology to anthropology and psychology. With each step, as has been pointed out already, man who in the Church had belonged to another world rather than to this and who had lived consciously and deliberately with reference to the hereafter gets ever nearer this or ever more truly in-and-of this. At first we see him with mechanics coming into a general but still only formal, then with biology into a distinctly more vital relation to this; until with the last, psychology, he is in an intimate and personal relationship. Certainly philosophy's present-day psychologism, as shown in pragmatism, experimental idealism, the many types of realism—radical, scientific, critical, "new," what you please—has quite outdone biology in its intimations of the unity of man and nature; because it has made, not merely organically living, but also consciously living man and nature most vitally and essentially one. Consciousness carries a far closer intimacy than organic life. Also for full understanding it should be remembered that today, quite as truly as mechanics or biology, psychology is to be looked upon as one of the real physical or rather natural sciences.

In spite of all that has been said my meaning may not yet be clear. In the sequence of philosophy's disciplines: theologism, mechanicalism, biologism, psychologism, no such story as was promised may have appeared. Possibly, then, at risk of tedious repetition, it may be well with a change not of the subject-matter but simply of the angle of view to add the following. Four conceptions: institution, mechanism, organism and conscious being, the human individual or person, have taken, each its turn in the order given, at holding the center of man's interest in and understanding of nature and have marked each an important step in man's progress, as he has taken possession of the earth. To science, even including under this term theology which has been found to have its place in the sequence and, as now I would add, including also jurisprudence which characteristically is science of the institution as temporal, formal, positive, theology being characteristically science of the institution as eternal and vital, as originally purposed and created and as maintained—to science, I say, the conceptions: institution, mechanism, organism and person, each one as it has come up, have referred to something special and definable, tangible and capable of positive identification. Definition and such identification are conditions of science. But in each instance, not less from demands of practical life than from those of theory, the handmaid philosophy has been in attendance and her service, faithful if not always appreciated, has induced a generalization from the particular and positive conception involved and so has opened the way to the next conception. Thus, as we have remarked, a dogmatic, supernaturalistic institutionalism gave place to a general and naturalistic mechanicalism. Even the creating cause and propelling force, acting from without, of the institution was made general, as is shown in mechanicalism's substitution of universal causation for the institution's dogma of only-once-upon-a-time causation or creation.[2] But also, thanks again to the service of philosophy, the conception of mechanism in its turn gave place to that of organism. What is an organism but general mechanism or mechanism become versatile, that is, natively mobile or active with the freed mechanical principle and so no longer bound to the routine of any single application of that principle, capable in other words of indefinite mechanical adaptations.

[2] Physical science's long dependence on the two principles, uniformity of *nature*—no longer just of the institutional life—and *universal* causation, has thus a most interesting historical antecedence.

In the person, finally, the generalization or the versatility is seen to be developed still further by the addition of conscious initiative to the adaptability.

So in the four conceptions, as in the four isms, we now have our story before us. The story does show, too, what was promised for it, namely, man's progressive adaptation to the natural environment, his gradual finding himself in nature, and it shows also in each important episode the constant service of philosophy, whose generalizations have really served science; not servilely, but in the vital way of inaugurating the new epochs instead of merely maintaining the old ones. Again, in indication of what the progressive adaptation and generalization have implied, the story shows an increasing versatility for human life. But particularly interesting as is this association of progressive adaptation with increasing versatility, it is for us here only to note how the history reveals philosophy as vitally, although never formally, scientific and thus shows how that lie about philosophy being unscientific was only a great truth in masquerade. That, unfortunately, professional philosophers have often neglected their great opportunity and even flagrantly abused it or that scientists themselves have sometimes turned philosphical and have so led their own science out of its particular captivity does not affect the matter at all.

Now, once more as to the progress from mechanicalism through biologism to psychologism, there is an interesting incident of the movement that merits some attention, although easily too much might be made of it. Not only does mechanicalism mark an early stage of the adaptation-process, in which man and his environment can hardly be said yet to have come into a close or vital unity, but also the early science of mechanics, especially as appealing to philosophy, was what might be called a gross mechanics, dealing as it did with the great bodies of the solar system, that is, with the gross and also the more distant factors of the physical or natural environment, Psychology, in sharp contrast, as the latest of the sciences, is concerned with the minute and very closest factors. For psychology the environment is no glorious and wonderful firmament, no orderly procession of the planets, impressive for the distances and the orbits and expressive of a great law, but is, instead, a close, sensuously felt and very real presence; not a matter, then, of distant view and contemplative wonder, but something immediately at hand.

No wondrous whirl of earth or sky,
Nor stars in ordered place:
But nearer things, like wind and rain,
That beat against one's face.

Such a difference, I say, between the earlier mechanics and the later psychology must not be taken too seriously; but, however superficial it may seem to be, it does in one more way show the progress of adaptation.

But, finally, of psychology and psychologism something special needs still to be said, lest there still be misunderstanding. Psychology is "science of conscious life" and in this character it might be taken for almost anything, including even the old-time "science of the soul." Present-day psychology, however, while truly being "science of conscious life," is also at the same time the latest natural science, as has been pointed out here. It is a natural science and to it such special branches of natural science as biology, physiology, neurology, are of greatest mediate value. It is itself, too, an experimental and laboratory science and so through mechanical methods and instruments it depends, albeit only mediately, on the narrowly physical as well as on the biological sciences. Accordingly in its character of being a natural science even while it is also psychology we may see the peculiar value of its coming at the close of the historical sequence. For it man and nature are indeed one. In fact its two characters or rôles, psychology *and* natural science, are so mingled that, just to allow ourselves a little amusement, its situation is not unlike that of the man who unfortunately or fortunately was so very thin that he could never decide, when in pain, whether he had a backache or a stomachache. Current philosophy, essentially psychologistic, knows not whether it is idealism or realism. A most happy predicament!

It would be interesting to close the story of adaptation as told here with some discussion of the moral and political, social and economic changes that have come with the changes in isms or in ruling conceptions. About an association of one group of changes with the other there can be no doubt. Science and philosophy are hardly epiphenomena. They are hardly accompaniments of the history of human affairs without being really and vitally of it. Their very reflection of the process of adaptation would seem to be conclusive evidence of this, if evidence were needed. But the story originally promised has been told and other matters, however interesting, must be left for another occasion.

THE PROBLEM OF THE HISTORY OF SCIENCE IN THE COLLEGE CURRICULUM*

By Professor HENRY CREW

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IF one were asked to describe in a single phrase the present-day position of the history of science in the college curriculum, I think he might fairly call it the "Ugly Duckling" of the program. For while it is just now receiving the treatment of an orphan, and the department of history has never seen fit to take this fledgling under its wing, the young bird has perhaps nevertheless all the possibilities of becoming a swan.

I hope to make my meaning clearer by saying a few words about the place for such a course, about the character of the course, and finally about the man for the course. In fact, I wish to offer a brief plea for a more human treatment of the fundamental sciences than they are now receiving, and I want to suggest that the most effective method of accomplishing this result is the introduction of courses on the history of science.

1. *First*, as one glances down the average college curriculum, and the faculty list, he may, I think, fairly admit that political and social history are well handled by men who are competent specialists—the men, indeed, who constitute the membership of your association.

Of the history of English literature the same may be said.

In the case of foreign literature, it is only after the student has passed beyond the technique required for easy reading, that he is introduced to the historical development of either the language or the literature. Economics, philosophy and psychology are frequently, at least, presented in the order of their chronological development, *i. e.*, in the historical order in which the facts were discovered—the order which Darwin has taught us is the natural order.

The modern college offers to its students practically only four lines of training—four topics which one might call "the modern quadrivium." These are

(i) Languages and literature.
(ii) Historico-political study and economics.

* A paper read before the American Historical Association at Cleveland, December 31, 1919.

(iii) The Philosopical group, including psychology, education, religion, logic, and mathematics.

(iv) The experimental and observational sciences; or, if you prefer, the physical and natural sciences.

Of these four topics, it is only the last mentioned which is *not* already receiving a more or less distinctly historical treatment. The typical natural sciences are, I suppose, *Zoology* and *Botany;* the corresponding physical sciences are *Physics* and *Chemistry.* These four sciences constitute the foundation upon which the other sciences rest; or, if any one prefers, they are the sciences which are in an especial way ancillary to all the others.

Physiology, hygiene, bacteriology, medicine, etc., naturally develop from biology, just as astronomy, geology and engineering come from physics and chemistry. Each of these four fundamental sciences does, of course, receive historical treatment in numerous curricula; but in many institutions no such course is offered. Professor W. F. Magie has published a complete treatment of physics written from the historical point of view. It might be called historical physics rather than a history of physics; since the emphasis is rather upon the clear and careful statement of the principles of the science, than upon its history. A combined course on the natural and physical sciences is offered by Professors Sedgwick and Tyler. My colleague, Professor Locy, has for many years given a very successful course on the history of biology. Numerous courses in the history of chemistry are given: more than twice as many as are given upon any other of the four fundamental sciences. Some are also offered in the general history of science, such as those by Professor L. J. Henderson, of Harvard, by Professor Walter Libby, of Pittsburgh, and by Dr. George Sarton.

The need for courses in the history of science appears to lie rather in these four fundamental sciences than in any subject outside: this, partly because the early history of these four subjects covers practically all the other sciences, and partly because the history of science, in general, appears to be quite too large a topic for one man to treat intelligently and sympathetically.

The theorem then which I propose is the following: Every college of liberal arts owes it to itself and to its students to offer at its earliest opportunity courses in the history of botany, zoology, chemistry and physics, in addition to the numerous historical courses already offered in other branches of the modern quadrivium.

2. Passing now to the character of the course which should be presented, this is, manifestly, always a question of time, place and man. Nevertheless, there are certain considerations which have, I believe, a wide validity among American colleges.

It was my privilege a few weeks ago to attend a lecture on *general physics* given by a young man who was offering the course for the first time. I was present on invitation and the comments which I am now about to make are precisely those which I gave to the young man himself at the close of his lecture.

The discourse was well illustrated by experiments; his demonstrations were clever and orderly; his explanations were clear and correct. He was evidently master of his subject, which on this particular morning happened to be *elasticity*.

But Hooke's Law was demonstrated without the slightest reference to that crabbed and crusty, but tremendously clever old bachelor, Robert Hooke, who lived in Gresham College and entertained the Royal Society of London so frequently and faithfully with the latest scientific results obtained sometimes by his own labors, sometimes from the labor of others.

This young instructor next proceeded to define Young's modulus and to derive the algebraic formula for it, without so much as a mention of that brilliant London physician, who at the beginning of the nineteenth century was perhaps the most variously accomplished man of science in England, the young Quaker, who as a medical student at Göttingen found ample time, between the more serious duties of a strenuous program, for lessons in dancing and horseback riding.

The elasticity of air was next expounded under the caption of Boyle's law, without any one of the one hundred and fifty auditors suspecting the existence of that charming old Irish bachelor, who largely held together and inspired the "Invisible College" out of which the Royal Society grew; the author of the "Skeptical Chymist"; "Robyn," as his sister called him; the intimate friend of Evelyn, Pepys, and Newton; director of the East India Company.

One can imagine that in his succeeding lecture my young friend would deduce and demonstrate with precision and elegance, the laws of collision, while his students are kept completely in the dark as to the three remarkable men—men of the first order—Huygens, Wallis and Wren—who first established these laws.

This bit of experience is mentioned, not in criticism of this young man, of whom I am an ardent admirer and to whom I have already said all I am saying to you, but rather to raise this question: Is science in America to be forever presented as a set of abstract principles, a set of generalizations, derived, it may be, in the first instance, from experiment or observation, but now formulated in the most impersonal way possible? Or is science to be treated as a distinctly human achievement?

Are not experimental results simply the facts which human beings have deciphered from the scroll of nature? Are the laws of physics and chemistry anything more than human expressions, adapted to finite human capacities, and accepted because of their convenience in human conversation? Is a theory in astronomy anything more than the "present policy"—to use Sir J. J. Thomson's phrase—proposed by some human observer for convenience in making prediction for later human observers? Are the bodies of plants and animals anything more to the student of biology than the source-books from which some human investigator has unraveled the laws of development and hygiene—the laws of birth, growth, death and disease? Do the various extensions of physical and natural laws to include new observations mean anything more than the fact that present investigators stand upon the shoulders of their fathers and thus acquire a wider and deeper vision?

If now this edifice which we call modern science—this body of "impersonally verified truth"—borrowing Professor Minot's excellent phrase—is an incomplete human structure, if it is after all merely a record of human thought, a formulation by the human mind, tremendously useful to the physician in the prevention and cure of human disease, valuable to the engineer in securing human comfort and safety, and human leisure for other forms of human activity; if, I say, science has all these human elements in it, why may it not be so presented to the student?

Let us, of course, concede that Dante's *Comedia*, with its human inferno, filled with striking pictures of all human qualities, the frail and the strong, the good as well as the bad, is a rare and powerful stroke of the human imagination. But what shall we say of the investigations of Copernicus and Kepler and Aristarchus, reaching out into vast space and finding unheard of orbits, speeds and distances?

Let us concede that Homer's story of Achilles going out after Hector is one of intense human interest. But what shall we say of the fight which Galileo maintained from boyhood to death, in such a skillful manner as to allow him, meanwhile, to accomplish his two great works and get them through the press?

Let us concede the lofty flight of the human imagination in which Milton casts Satan out of heaven. But what shall we say of the many superstitions cast out of the human mind by Milton's contemporaries—Huygens, Newton, Pascal, Harvey and Leeuwenhoek?

We are all glad to recognize the rare and human beauty of Tennyson's verse; but let no one imagine that he is either nodding or stepping down when he sings the story of evolution. Is the exquisite flight of genius in which his contemporary, Clerk-Maxwell, describes the essential features of that wonderful human convenience called wireless telegraphy, a quarter of a century before the art was realized in experiment, any less appealing?

Now having made all these concessions and as many similar ones as you like, does there not remain sufficient human interest in science to justify its presentation as a human achievement, rather than a heartless, bloodless, colorless, body of cold rigid fact? Tragedy and comedy, pathos and humor are, of course, never found in nature. We must seek them in human nature; the history of science is full of them. "The fairy tales of science and the long results of time" with which Tennyson nourished his "youth sublime," offer as large a field for the imagination as any other theme of poetry; the one difference lies in the fact that the scientific imagination must be bridled by reason; but this curbing of the imagination by reason is all that we mean by clear thinking; and clear thinking is the goal of all our work.

Now, I have not even mentioned the "humanities." I shy at the term, only because I fear it has come, in many quarters, to mean almost the exact opposite of the spirit which prompted the composers of Greek and Roman literature, and also the opposite of that which was intended by the men who introduced the term in the fifteenth century. Nevertheless, I trust, I have fairly indicated the possibility and desirability of treating science in a humanitarian manner and of making it one of the real humanities of the modern curriculum. If accuracy of judgment and clearness of thought are to be sought in the new quadrivium, they will be found most easily and most frequently through the study of language and science. It is especially up to those of us who teach the history of science to present its human aspects—which are not for a moment to be identified with its merely practical and commercial aspects—and thus redeem the word "humanity" from the narrow sense in which it is employed at Oxford and in the Scottish universities.

3. Let us now pass to the man who ought to offer such a course; that is, a course which shall present science as an evolution of the human mind—as a growth rather than as a finished product. There is a helpful French proverb to the effect that "at thirty every man is either his own physician or a fool," suggesting that at an earlier age he is too busy with other matters to care much about his own health. It is somewhat so with the young man who has just made his doctor's thesis in science. He is so much absorbed in the beautiful unity which he has recently discovered in his subject, and so eager to get a still wider and firmer grasp of his specialty that he finds little time to spend upon its developmental history.

With the recently appointed assistant professor, the circumstances are not very different. He also has little time for the past. "Dead men ride fast horses." He is too busy with his own research along his chosen line. He can not leave it except for the perfunctory teaching of those courses which, in common decency, he must offer. If one sugests to him the possibility of his offering a course in the history of his topic, his reply resembles a stanza in which Mr. Kipling once declined an invitation to dinner from the boys at Yale.

> When you grow older, and skin your shoulder
> At the world's great wheel in your chosen line,
> You'll find your chances, as time advances,
> Of taking a lark are as slim as mine.

This was indeed my own view for many years. Time spent on the history of physics was time spent on a luxurious lark. "The years go fast at Oxford."

The full professor is not far from forty years of age. With him the circumstances have begun to be a little different. The connection of his own work with that of others is more evident. The philosophy of the subject is interesting him more and more. He is now aware of the fact that the lives of the founders of the Royal Society are inseparable from the civil wars of England, the great fire and the great plague of London; that Darwin and Kelvin are just as essentially features of the Victorian era as are Gladstone and Tennyson; that Pascal and Torricelli and the Accademia del Cimento are inseparable from the religious history of their times—the age when science was supported, if at all, by royal patronage. "Knowledge comes, but wisdom lingers." Here then is the man who ought to teach the history of science. One who is familiar with the technique of investigation. One who knows the mode of thought employed in research. One who is willing to take the pains and pay the price of making some small contribution to human knowledge: one who is able to bend the English language to his own purpose.

This man will be too keenly aware of his limitations to undertake the history of *all* the sciences, and will find the available hours brief enough for a history of his own science. An illuminating confession along this line is the public address given by the distinguished editor of the *Review* when, overwhelmed with the rapid development of mathematics, he broke off in the midst of a brilliant university career to take up newspaper work. A similar confession came to me a few weeks ago from a man who had left his favorite field for ten years of executive work, only to find on returning to the field that the landscape was covered with a new and entirely unfamiliar growth.

The outstanding difficulty in the way of any man of science giving a historical course is that scholar's instinct which tells him that, as a rule, he lacks the proper historical background, and does not have the easy confidence of the man who has been long in training at general history. Nevertheless, if we can find men of breadth and vision, men of at least forty years of age, who are willing to present the developmental histories of the fundamental sciences, especially physics, chemistry and biology, and to present them in such a way that they will furnish the student with a generous culture, and put him *en rapport* with his environment, the place of our subject in the college curriculum will soon be established.

Nor is the proposition one which we need fear to urge upon our university presidents, our colleagues or our students; for just as water is the great, common and dominating feature of the globe, so is science the one common feature of all nationalities and all civilizations. Science does not differ from nation to nation as do language, religion and politics. The history of science is therefore something almost as wide as the human race and deserving of humanitarian treatment.

THE PLANETESIMAL HYPOTHESIS IN RELATION TO THE EARTH

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INTRODUCTION

CHAMBERLIN'S recent book on "The Origin of the Earth" was welcomed by geologists as the most complete statement yet made for the planetesimal hypothesis of the origin of the planets.[1] Barrell has given a convenient summary of the hypothesis, in the following words:

> The volume of a star [the sun] represents a balance between expansional and condensational forces acting on a vast body of gaseous nature. On the approach [of another star] their mutual gravitation would produce tidal forces diminishing their self gravitative power along the line between the centers and give the expansive forces opportunity to rise to explosive violence along that line. This tidal force is actually greatest at the centers and would lead to a very deep-seated disruption. The gas bolts shot out would, owing to viscous resistances, be pulsatory, and separated nuclei would therefore be expelled. These nuclei and the associated dispersed matter would, on the nearer side, be dragged sideways by the passing star. On the reverse side the symmetrical tidal protrusions would be left behind, the sun being dragged more than they. The result would be a spiral nebula, a form which would meet the dynamic demands of the existing solar system. . . .
>
> The building up of the planets is believed to have followed three stages: first, the direct condensation of the nuclear knots of the spiral into liquid or solid cores; second, the less direct collection of the outer, or orbital and satellitesimal matter; third, the still slower gathering up of the planetesimal material scattered over the zone between adjacent planets. This third factor in Chamberlin's view is regarded as very important and he believes this diffused matter contributed much of the earth substance, very slowly and in a dust-like form. This is one of the critical points in the details of the theory, unessential to the larger framework, but upon which turns much of the development of the following argument. In earth-growth the denser planetesimal dust, Chamberlin argues, tended to be somewhat segregated into the primitive ocean basins and served to maintain in them, as the earth was built outward, a greater density than in the elevated zones between. . . .
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> The earth is conceived as beginning to hold an ocean by the time it contained 30 or 40 per cent. of its present mass. . . .
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> The particles of radioactive matter [in the earth] would tend toward

[1] T. C. Chamberlin, "The Origin of the Earth," University of Chicago Press, Chicago, 1916.

local heating and fusion. Thus they would be progressively concentrated into the outer shell of the earth by the rising of igneous matter. Pulsatory stresses from body tides and from shrinkage are regarded as the chief agents leading fused matter outward and serving to maintain the earth's body in solid form.[2]

On the astronomic side this conception of the solar system represents one of the grandest achievements of modern science. The distribution of masses and momenta, the directions of revolution and rotation, and the constitution of each member of the system, so far as ascertained, are explained with such a degree of probability that astronomers are becoming more and more impressed by the planetesimal hypothesis. However much increasing knowledge may change premises and conclusions, the critical and creative work of Chamberlin, Moulton, and their associates has resulted in stimulus to many minds and marks a permanent advance toward a final understanding of the earth's beginning.

Chamberlin was led to his great idea while studying ancient climates, and it is natural that he has attempted to apply his cosmogony to that later part of terrestrial history which is covered by geology proper. He has recognized the exceeding difficulty of this extension of the hypothesis beyond the astronomic limits, but has courageously attacked the problem as it affects the general distribution and shapes of the existing continents and ocean basins; hence the making of assumptions which have no vital connection with the splendid cosmogony itself. Some of the subsidiary assumptions are doubtful, if not quite inadmissible, and it now looks as if general recognition of Chamberlin's working hypothesis would have been hastened if it had been announced without direct reference to the later, geological, history of our globe.

One doubtful postulate is that the earth has been essentially solid since the time when it had less than half its present mass. To a discussion of this point the present paper is devoted; the postulate is hard to reconcile with the main planetesimal hypothesis itself, on the one hand, and with leading facts of astronomy and geology, on the other.

Some Implications of the Planetesimal Hypothesis

Neither the mass, nor the temperature, nor the dynamics of the original earth-knot or nucleus are deducible from the root premise of expulsion from the sun. According to some astronomers, the visible spiral nebulæ are not homologies of the plane-

[2] J. Barrell, *Science*, Vol. 44, 1916, p. 241.

tesimal nebula. In any case one can not infer from the spirals, even in rough measure, the state of the earth nucleus immediately after its expulsion. The general hypothesis gives no direct information concerning the ratio of the mass of the knot to the mass of the existing earth. Around the earth is now a "sphere" (spheroid) of control within which our planet's gravitative influence surpasses that of the sun. The sphere of control is roughly 5,000,000 times the volume of the earth. Within so great a space nearly all of the earth's matter might have been aggregated at the nuclear stage, in spite of the high temperature prevailing at the initiation of the earth-knot. If so, condensation of the earth-knot by its own powerful gravitation would be rapid, with the consequent speedy increase of temperature. Initially hot enough to be completely gaseous, the nucleus radiated much heat, but this effect on temperature was at least partly offset by the development of heat through self-compression and chemical changes. A very large part of the initial heat and of the original potential energy would have to be lost by radiation before a liquid state were assumed and still more before a solid crust could be developed. According to Lane's law, radiation and consequent contraction would actually raise the temperature of the knot if its gas behaved like a "perfect" gas. The potential energy of such a system is far from being measured by the amount of the contraction. Doubtless a much greater part of the potential energy would manifest itself in the form of heat given off during chemical reactions in the nucleus, which was initially composed of highly dissociated elements.

In short, the original earth-knot was, by hypothesis, a true furnace. Its generation of heat must have long continued, even if the initial mass were only one quarter of the globe's present mass. The vital question arises as to whether the gaseous knot would be solidified by cooling before most of its accretion was accomplished. *Rates* of heating, *rates* of cooling, and *rates* of accretion, as well as the initial mass and temperature of the knot are involved, and the general hypothesis bears no implication concerning any of these quantities.

Chamberlin appreciates this fact and concludes that "the temperature of the innermost core of the earth" must remain "an open question." He also states that "the mass of the planetary nucleus may have been so large and the ingathering of the planetesimals may have been so rapid, by hypothesis, that a molten or even a gaseous condition could have arisen. In the case of the larger planets such a primitive state is quite within the limits of the probabilities. The case of the earth is debatable."[3]

Assumption of the Earth's Early Solidity

Yet, notwithstanding his own unescapable conclusion, Chamberlin believes that the earth, with a mass only about one third of its present value, was already well crusted, if not essentially crystalline to the core. He assumes that a water ocean could then lie on the earth's surface, and that the heat of self-compression, chemical heat, and heat generated in radioactivity have never sufficed, since this embryonic stage, to melt the surface shell of the globe. With these assumptions, which are not implicit in his main, astronomic hypothesis, Chamberlin proceeds to picture the juvenile shaping of the earth, in the longest chapter of his latest book. Further difficulties appear as the speculation is developed, leading to other unproved assumptions. The latter are not of immediate concern, since they rest on the conception of early, and thenceforth permanent, solidity for the earth, which is the thesis specially questioned in the present note.

Testimony of the Other Planets

The general hypothesis assumes similar origins for all the planets. Jupiter, Saturn, Uranus, and Neptune have densities either a little less than that of water or a little greater, contrasting with the mean density of the earth, 5.5. There are apparently only two possible explanations of the contrast. The outer planets must be greatly expanded by heat, or else they must be composed of hydrogen or other elements of low atomic weights.

Each planet represents a major belch from the sun and yet also a minute fraction of the sun's substance. Now studies of the sun's photosphere, "reversing layer," and "spots" show that its surface shell, down to a depth of many hundreds of miles, is composed of both heavy and light elements. Heavy elements are likely to be still more abundant in deeper shells. We can not assume that the sun, because of higher temperature, was a "hydrogen" star when the planetary belches took place, and that the gas-bolts were shot out from the outer layer of hydrogen. This possibility is at once excluded by the facts known about the constitution of the four inner planets, the asteroids, and the satellites of the planets. Thorough mixture

[3] T. C. Chamberlin, "The Origin of the Earth," Chicago, 1916, p. 164, and "The Tidal and Other Problems" (Carnegie Institution Publications, Washington, 1909, p. 18).

of heavy and light elements in the sun at the present time is plainly due to convection and explosion.[4] Both actions would doubtless have been still more intense when the sun was hotter. If, as Chamberlin thinks, the belching were due largely to explosions originating in great depth, heavy elements could hardly fail to enter into the composition of all the major belches. The greatest belches should have tapped deeper layers than those tapped by the weaker earth-belch, giving a larger percentage of heavy elements to the four outer planets.

On this point Chamberlin writes: "The distal portions of the protuberances would be obviously formed from the superficial portions of the sun, while the later portions of the ejections forming the proximal parts of the arms would doubtless come mainly from lower depths, and hence probably contain more molecules of high specific gravity."[5] But is that conclusion justifiable? If all of the planetary material were put back in the sun, the sun's diameter would be little changed; its mass would be increased by less than one seventh of one per cent. If a mass equal to either Neptune or Uranus were removed from the sun's surface shell, the depth of the layer known to be now affected by powerful convection would be decreased by only a small fraction. The supposition that, at the birth of the planets, convection did not affect the sun's layer which was disrupted, is not easy to reconcile with the sun's present condition. To suppose that deeper layers were not tapped is to exclude the strong influence of explosion, a basal postulate of the general hypothesis. Moreover, the smaller the mass ejected, the more superficial would be the solar shell involved. All these considerations make it difficult to believe that there would be any drastic or systematic variation in the material ejected successively from the sun. One might even raise the question whether the general hypothesis demands that the earth-belch really followed in time the Jupiter or Uranus belch. If, on the contrary, the earth-belch were the older, it should, according to Chamberlin's principle above-quoted, have density lower than either of the other two; lower, too, because the earth-belch was the weakest of the three. Finally, the densities of at least two of Jupiter's satellites are too high to be explained by the hypoth-

[4] The experiments of H. Bénard (*Rev. gén. Sciences*, Vol. 11, 1900, p. 1261) suggest that the granulation of the sun's surface may be due to the development of a cellular structure which is expected in any fluid layer uniformly affected by convection.

[5] T. C. Chamberlin and R. D. Salisbury, "Geology," Chicago, Vol. 2, 1906, p. 58.

esis that their parent belch was made of pure hydrogen or of hydrogen mixed with helium.

Much more probably every major belch from the sun was made up of elements now engaged in the solar tornadoes—calcium, iron, barium, sodium, magnesium, silicon, etc., as well as hydrogen and helium. In fact, from a passage quoted above, Chamberlin seems to have abandoned his early view, now favoring the conclusion just stated. Perhaps yet more surely than the Laplacian hypothesis, the planetesimal hypothesis demands that all planets shall have a large proportion of elements with high atomic weights. If so, the outer planets must have very high temperatures, as so long held by astronomers.[6]

We have, then, half of the planets still so hot as to be gaseous, although, by hypothesis, they are nearly as old as the earth and are probably composed of material which is much like the average material of the earth.[7] At this late day the four outer planets must be losing heat many times faster than the earth is losing heat through a solid crust and still they are incomparably hotter than our globe. According to the planetesimal hypothesis, they are so hot because of their size. If the common mechanism produced in four full-grown planets temperatures sufficient for nearly complete volatilization of highly refractory substances, temperatures persisting after more than one hundred million years, is it reasonable to assume that the mechanism failed to produce the much lower temperature needed for surface liquefaction of a fifth planet a hundred million years ago? Do not these homologies suggest yet more—a gaseous condition for the earth after it had attained its present mass?

In summary, the planetesimal hypothesis leaves indeterminate most of the essential factors affecting the earth's successive temperatures, namely, the ratio of nuclear mass to

[6] Of course density can not give accurate intimation of temperature. Saturn, for example, with a little over half the density of Jupiter (0.7 against 1.3, water being 1.0), is not necessarily the hotter. Moderate differences in chemical constitution, together with differences in internal pressure, must also enter into the causes for the contrast.

The reasoning is not affected by the possibility of a solid core for each of the outer planets. The core must be relatively minute, for otherwise the average density would be too high to match the facts. With correspondingly great depth for the planetary atmosphere, involving pressures of tens of thousands of earth atmospheres, the average density of the planet could be low only in case the main, gaseous part of its body had high temperature.

[7] The approximate identity of age is implied by the basal postulate of disruption, for a visiting star would vitally affect the sun for only a few years, at most.

planetary mass, the initial temperature of the earth-knot, the rate of accretion, the heating factors, the cooling factors, and the absolute time involved. Hence the present condition of the other planets ought to have special attention by any one who attempts to trace the earth's history down into "Archean" time. Perhaps we can hope for no better evidence in nature on the subject of the early temperatures of our globe.

An Early Crust a Blanket on the Earth Furnace

If, however, radiation did actually overtake heating in the young earth, with the development of a solid crust, the general hypothesis implies the likelihood that this crust would be but temporary. So far as densities are concerned, it might have been stable if the earth had already, because of fluidity, become stratified by density. On the other hand, the crust, an efficient blanket, must have brought radiation to a very low minimum. Later, considerable accretion of the earth nucleus could not fail to develop new heat by self-compression and chemical rearrangements under the new, ever-changing conditions of internal pressure. The changing conditions would affect material at all depths. The heat waves so generated would pass outward with great slowness, for convection was largely in abeyance if the earth were layered according to intrinsic density of its materials. A relatively moderate heat-wave of the kind, moving outward for but a brief time, would suffice to re-melt the crust. Each time that the surface shell became fluid, gravitative differentiation would be more perfected near the surface, with resulting retardation of convection. On one of the reasonable assumptions regarding the young earth, therefore, the planetesimal hypothesis seems to demand a cyclical or rhythmical change of state for the earth's surface shell, analogous to that observed in the lava lake at Kilauea or in other typical volcanic vents.

Be it observed, nevertheless, that the general hypothesis, as announced, does not necessitate belief in crustification (or in solidification at any depth) of the earth until it had attained its present mass.

Testimony of the Moon

The volcanic nature of the lunar pits and maria is generally credited and seems to be implied by the planetesimal hypothesis. If the pits and the vast areas of the maria were due to the impact of bolides, these bodies would, by hypothesis, be planetesimals. They would have been practically the last to fall into the lunar nucleus, for the visible depressions are not appreciably veneered with planetesimal particles of smaller dimensions. Similar masses would have fallen into the earth during the last stage of its growth. Yet nowhere on continent or in ocean basin is comparable topography to be found. The progress of erosion can hardly account for the disappearance of every trace of such gigantic features. Moreover, the symmetry of each lunar pit does not agree with the impact hypothesis, if the great bolides were planetesimals, added to the moon's mass in the normal way.

If, by fair interpretation, the planetesimal hypothesis implies a volcanic origin for the lunar depressions, the main hypothesis also implies that, after reaching full size, one of the smaller aggregations in the solar system had internal heat enough to permit eruptivity on a scale vastly superior to the scale of volcanism on the present earth. In more or less close succession all parts of the moon's surface seem to have been affected by igneous eruption. The colossal lava-floodings of the maria have been accompanied by subsidence of the pit-covered crust in the corresponding areas, suggesting (as in the earth's similar cases) that the flooding lavas were drawn from a non-crystalline substratum close to the moon's surface.

According to the planetesimal hypothesis, the moon's volcanic heat was generated largely by self-compression and chemical rearrangements in a body with mass only one eightieth of the earth's mass. The facts are not opposed to the conception that the moon was itself actually molten at the surface just before the satellite took on its present characteristics. In any case the total heat generated in the moon must have been enormous. By hypothesis, the total heat generated in the growing earth-knot was many multiples of 80 times greater. Can one doubt that general volcanicity in the one case would be fairly matched by complete superficial fluidity in the other?

Cause of the Earth's Rigidity

The combination of the facts known about the solar system thus interpreted by the planetesimal hypothesis furnishes a cumulative argument in favor of assuming a molten or even gaseous state for the earth's surface shell after our globe had grown to full size. Chamberlin's selection of a strongly contrasted possibility of his cosmogonic scheme is due in part to overemphasis on some elements of the scheme, especially those contrasting with essential features of the Laplacian cosmogony.

Other reasons are found in certain assumptions based on modern geophysical studies.

In the first place, he stresses the familiar principle that the melting temperatures of rock minerals are raised by pressure. Again it is a *rate*, the rate of the raising, which is absolutely vital to his argument. But it will be long before the relation of pressure and melting temperatures for the earth's core materials at their actual depths can be fixed. Meantime, one thing seems certain: pressures hundreds of times greater than those inside the earth are unable to cause the crystallization or even the liquefaction of most of the sun's substance; else the mean density would be very different from what it is. Not much weaker is the belief of astronomers concerning the non-solid nature of most of the materials in Jupiter, though these are under pressures far transcending mean or maximum pressure in the earth. Appeal to the principle here discussed has, in fact, been much overdone by many authors in their efforts to explain the earth's high rigidity.

Secondly, the proof of the earth's present high rigidity is taken by Chamberlin to mean solidity, that is, crystallinity, for the whole interior of our globe except for local "tongues" of melted rock. Even if this assumption were correct, it does not follow that the earth was similarly crystalline to the core during the period of accretion. But high rigidity does not necessarily mean crystallinity. With uniform laboratory pressures the viscosity of paraffin increases so much faster than the viscosity of nickel steel under the same pressure, that the hydrocarbon finally becomes more rigid than the steel. Rock glass, a supercooled liquid at ordinary pressure and temperature, is much more rigid than many crystalline solids. Under high, uniform pressure glass is many times more rigid than nickel steel. Under pressures of from 10,000 to 500,000 or more atmospheres, rock glass might attain, at high temperatures, degrees of rigidity quite competent to match the earth's stress-strain relations so far demonstrated. Neither seismic nor tidal vibrations within the earth demonstrate crystallinity for below the surface. If the earth's core is crystalline, the proof thereof must lie in some other direction, as yet unguessed.

For some geophysical inquiries it may be a matter of indifference whether the earth's rigidity is due to crystallinity plus pressure or to pressure alone; but Chamberlin's speculations on the shaping of the juvenile earth and on the cause of igneous action are critically affected by his choice between these alternatives.

Planetesimal Hypothesis in Relation to Igneous Action

The growing earth being a highly efficient furnace, by hypothesis, crystallinity could not be preserved for the interior materials, if the central heat were not quickly removed. To support his idea that liquefaction of the interior did not take place during most of the period of accretion, Chamberlin has imagined a special mechanism for the removal of heat. This involves selective mutual solution of the "more fusible" crystals and, through tidal kneading of the remaining solid materials, the upward streaming of the new magmatic "tongues" to the earth's surface. The heat is there dissipated by radiation and no longer threatens the stability of the solid state for the interior materials in general. The continuance of the crystalline state inside the earth is thus explained by the generation and rise of magmatic "tongues," and the generation and rise of the "tongues" is in turn explained by assuming a crystalline state inside the earth. The argument has some resemblance to reasoning in a circle.

Relative Rates of Generation and Transfer of Heat

The rise of the magmatic "tongues" is attributed by Chamberlin to tidal kneading of the earth's body. Barrell has pointed out the comparative feebleness of the tidal stresses now affecting the earth's interior. Those affecting the small, young earth at a time when the moon's material was still largely dissipated in the planetesimal state must have been much smaller still, unless the two bodies were then closer together. However this may be, the problem of the *rate* of heat transfer by the rise of "tongues" as against the *rate* of heat generation in the earth's interior is of first importance. The planetesimal hypothesis by no means implies that the special cooling mechanism just described was more efficient than the earth-furnace during the period of accretion. If the development of heat were more rapid than the heat loss, to the point of producing general fluidity, the imagined mechanism of extrusion and differentiation of material, as well as the mechanism of cooling itself, would be destroyed.

Nevertheless, Chamberlin prefers the view that there has been a stupendous sorting of the terrestrial substances through the expulsion of "tongues" working outward in an essentially crystalline earth. He writes:

> The mutations of the inner earth may be summarized as a single prolonged process by which the more fluent, solvent, and lighter material of the earth-body was concentrated toward the surface, while the more immobile, refractory, and heavier matter was concentrated toward the

center. The result may be pictured as a central core dominated by metallic alloys and a thick enveloping sphere dominated by silicates.[8]

The core residuum is supposed to have been originally crystalline, but recrystallized, without fusion, after the manner of the familiar metamorphic rocks. During these secular changes, "the arrangement of atoms and molecules in the heart of the earth was probably controlled in the main in the interest of the internal fixation of energy and was predominantly endothermic." Chamberlin assumes, on the other hand, that energy was not stored in the radioactive elements, which have continued their break-up throughout the earth's history and at all depths. Since radioactivity is taken to be the chief source of the latent heat represented in the molten "tongues," that assumption is necessary, but it is immediately seen to rest on an unsounded mystery. The conditions for the potentialization of energy in the radioactive elements are quite unknown, but those conditions may include very high pressure and temperature, such as those prevailing deep in the earth. The laboratory tests so far made are clearly inadequate to deal with the profound mystery, the existence of which prevents confidence in the extrusive mechanism imagined and in the allied argument for permanent crystallinity of the earth's core.

Dominant Magmas

Further, differential fusibility or solubility of planetesimal materials can hardly explain the visible eruptive rocks. The dominant magmas whence these rocks have come are the basaltic and the granitic, each of nearly uniform composition from continent to continent and from ocean basin to ocean basin, and throughout geological time. They are strongly contrasted chemically. *Both* can not be the "most fusible" or "most soluble" constituents of the earth. If one is a late differentiate of the other, field evidence of the splitting might be expected; there is none.

Nor does Chamberlin's speculation explain: (*a*) the fact that the bulk of the visible granitic rocks are intrusive, while the bulk of the basaltic masses are extrusive; (*b*) the fact that the pre-Cambrian basement terranes are on the average granitic, while the eruptives of the open-ocean floors are almost entirely basaltic or derivatives of basalt. The imagined "tongues" should not have risen from the earth's interior in this selective way. On the other hand, mere inspection of the quantities involved (including the oceanic salts) forbids the notion that the granites of the continents represent a re-melted residue of secularly weathered basalt.

[8] T. C. Chamberlin, "The Origin of the Earth," Chicago, 1916, p. 240.

Crustal Subsidence Connected with Eruption

Another fact not readily understood according to Chamberlin's mechanism of igneous action is the strong subsidence of the floors of major volcanic bodies and of laccoliths (lopoliths). The best theory of these sinkings refers them to the necessity of crustal collapse over the respective subcrustal areas whence the erupted magmas were drained. Each subsidence is readily comprehended if the feeding magmatic reservoir is a nearly or quite horizontal layer, local or general, below the crust. There is no reason to suspect that "tongues" from the deep interior would spread out at just the right depth to explain the many observed sinkings of the crust.

Eruption Largely Concentrated in Mountain Chains

Most of the post-Cambrian eruptivity of the continents is concentrated in orogenic belts, leaving the larger part of the continental surfaces free from igneous rocks. For example, the North American Cordillera has been many times, at long intervals, the scene of magmatic eruption, while the Great Plains region of Canada and the United States has witnessed little activity of that kind. Mid-continent ranges, like the Alps or Urals, and their respective environments suggest that this contrast has little to do with the meeting of continent and ocean basin. There is no apparent reason why magmatic "tongues" from the earth's core should so persistently reach or approach the surface only along the belts where the earth's surface shell is periodically wrinkled or broken. A genetic connection between orogeny and igneous activity must be assumed, but it becomes intelligible only on the supposition that the locus of eruptivity is in every case relatively close to the surface and not in the deep interior of the globe.

Eruptive Sequence

Finally, Chamberlin's speculation needs much supplementing before it can account for the general order of eruption in continental petrogenic cycles. The order is from "basic" to "acid," though often the sequence is closed by minor eruptions of "basic" magma. For reasons elsewhere detailed, this sequence seems to imply initial eruption of basaltic magma, followed, in batholithic provinces, by considerable assimilation of solid "acid" rocks, entailing differentiation of the new solutions.[9] The chief rock assimilated in batholithic chambers seems to have been pre-Cambrian gneiss of granitic composition. During post-Cambrian time the only primary magma erupted has probably been the basaltic; if so, all other pre-

Cambrian eruptives are of secondary origin. On the other hand, the older pre-Cambrian granites and gneisses, composing most of the continental plateaus, are not in similar relation to basaltic magma and must be regarded as independently erupted. If their eruption took place by the "tongue" mechanism, the composition of these melts must have been changed from the granitic to the basaltic during some part of the pre-Cambrian era, though long after the earth had reached its present size. No reason for such a systematic change is in sight if the "tongue" hypothesis of eruption be regarded as valid.

Conclusions

Many other facts of igneous geology are inexplicable on a cosmogonic theory which postulates a general solid (crystalline) condition for the earth during most of its growth. This is, however, not a necessary feature of the planetesimal hypothesis, which, apparently sound itself, points rather to the probability of a fluid state for the earth both before and for some time after accretion was completed. In a problem where so few of the essential elements can be quantitatively defined, the condition of the other planets, the satellites, and the sun is of primary importance. The planetesimal-nebula hypothesis is partly founded on the analogy of the visible spiral nebulæ. Analogy might be as fairly used to test it. However, the other planets are homologies, by hypothesis, and their testimony gives ground for deductions yet stronger than those from pure analogy. There is nothing in the dynamics of the planetesimal cosmogony which forbids belief that the earth long ago passed through a Jovian stage. To assume that its surface shell was not at least liquid when the earth attained full mass is seen to be hazardous when one reflects on the relatively slight difference between the efficiency of an earth-furnace competent to keep that shell liquid for a time and the efficiency of an earth-furnace which kept the thermal gradient and solution (fusion) curve "identical" (Chamberlin) within the globe. The identity of these two curves could persist only through a balance between heating and cooling, a balance incredibly delicate in view of the suggested origin of the planets.

Making the more probable deduction from Chamberlin's cosmogenic scheme—an earth once largely fluid from the surface downwards—the facts of geology are better understood. Among the leading facts are: (1) the density stratification of our planet, induced by early gravitative differentiation in gas or liquid; (2) the dominance of gneiss and granite in the early

[9] R. A. Daly, "Igneous Rocks and Their Origin," New York, 1914.

pre-Cambrian complexes, which represent the rearranged material of the earth's primitive crust (a surface differentiate of low density); (3) the dominance of basalt in fissure eruptions, with other facts indicating the existence of a world-circling basaltic *couche* below the crust (the upper layer of Suess's "Sima"); (4) the genetic connection between geosynclinal downwarping and mountain-building with igneous eruption; (5) the number, lengths, and wide distribution of dikes of uniform, diabasic composition; (6) the subsidence of the floors beneath major volcanic masses and of the floors beneath the greater laccoliths; (7) certain stress-strain relations of the earth, since the high rigidity of the earth, for example, may be partly due merely to primitive differentiation according to gravity.

It may be added that the composition of the ocean ought to be quite different, if the ocean began its long life when the earth's mass had only one third or one half its present value. For, by hypothesis, the earth then had an atmosphere, rock-weathering was under way, and river salts were pouring into the ocean. Also by hypothesis, the subsequent growth of the earth was very slow. During that long accretional period, the soluble sodium must have entered the oceanic solution, most of it to remain there to this day. As a matter of fact, the sodium content of sea-water is now embarrassingly low if the earth is no older than the visible pre-Cambrian terranes!

Applied to the earth's later history, the planetesimal-nebula hypothesis thus appears to overlap the gas-nebula hypothesis. In each case a fluid state for the earth is fairly deducible from the astronomic premises. Since the objective facts of astronomy and of geology, especially igneous geology, point in the same direction, the assumption of primitive fluidity seems to be the best working hypothesis on which geology can be based. Meantime, our profound ignorance of the behavior of silicate and metallic melts at very high temperatures and pressures should prevent fixed opinion concerning the cause of the earth's high rigidity. Similarly, the mystery attaching to the original potentialization of energy in the radioactive elements makes uncertain the true relation of radioactivity to the earth's internal heat. As critical facts are slowly accumulated, the greatly appealing planetesimal hypothesis of Chamberlin and his co-workers may well serve as a foundation for geological philosophy, though the subsidiary doctrine of essential crystallinity for the earth throughout geological time be not accepted.

THE MECHANISM OF EVOLUTION[1]

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VI. The Cellular Basis of Evolution

IN sexual reproduction which is well nigh universal among animals and plants adult organisms can give rise to other adult organisms only through the germ cells, and just as the germ cells are the only living bond between generations, so also they are the only living bond between species. Hereditary likeness and specific constancy are due to the persistence of germinal organization; hereditary variation and evolutionary changes are caused by changes in this germinal organization.

1. *Modifications of Cytoplasm*

Of all portions of the germ cells the cytoplasm undergoes the most extreme modifications. The remarkable changes which it passes through in the course of embryonic differentiation have been referred to in preceding pages; but while these changes constitute the sum and substances of individual development they do not affect heredity or evolution. It is certain that the cytoplasmic differentiation of nerve, muscle and gland cells have no direct influence upon the hereditary constitution of the germ cells and it is very doubtful whether the cytoplasmic differentiations of the germ cells themselves affect their hereditary value. The highly differentiated cytoplasm of the spermatozoon has apparently no influence even on the development of the egg which it fertilizes and while differentiations of the cytoplasm of the egg do control some of the most important orientations of development there is no satisfactory evidence that these differentiations are not the result of the environment or of the activity of chromosomes during early stages in the formation of the egg.

The only cytoplasmic modifications or mutations which could be of evolutionary significance would be those which might be transmitted to other generations through the cytoplasm of the germ cells and chiefly through that of the egg cell. One such type of cytoplasmic transmission, which must however have played a very small rôle in evolution, is found in living bodies such as plastids, symbionts or parasites which live and multiply

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 17, 1917.

in the cytoplasm and are carried from one generation to another in the cytoplasm of the germ cells.

On the other hand the orientations of the egg cytoplasm initiate and to a large extent determine the character of all the orientations of development and if it could be proved that the polarity, symmetry, or pattern of localization of the cytoplasmic substances of the egg are carried over from generation to generation, modifications of these differentiations would be of profound influence in evolution. I have elsewhere shown that such a marked modification as the total reversal of the symmetry of the body can be traced to a reversal of the symmetry of the cytoplasm in the unsegmented egg and that changes in the orientation of organs and systems such as are found in vertebrates as contrasted with invertebrates can be most readily explained by tracing them back to changes in the localization of formative substances in the cytoplasm of the egg. The problem of the origin of one phylum or type from another has always involved as one of its chief difficulties such changes in orientation and localization and in a previous section we have seen how earlier evolutionists blundered in attempting to explain how one developed animal might be transformed into another by turning it upside down or inside out. Such changes which are utterly impossible in developed organisms might readily be brought about by relatively slight changes in the cytoplasmic localizations of the unsegmented egg.

Furthermore the integrating and coordinating factors in ontogeny and phylogeny are no less important than the differentiating factors; indeed in some regards they may be said to be more important for without these not only development and evolution would be impossible but organisms would cease to be organized and life would cease to exist. At present we know that many of the integrations of development can be traced back to the polarity, symmetry and localization pattern of the egg cytoplasm. If these differentiations and integrations of the cytoplasm are carried over from generation to generation, then modifications of them must be a very important process of evolution. On the other hand if these differentiations arise anew in each egg cell, as do the various differentiations of tissue cells, through the interaction of nucleus, cytoplasm and environment. then evolutionary changes in orientation may find their ultimate causes in changes in the nucleus rather than in the cytoplasm.

Certain changes in polarity, symmetry and localization of formative substances in eggs may be brought about experimentally by subjecting them to strong centrifugal force but such changes are usually of a temporary character and in no instance have subsequent generations been studied to find whether these changes are ever inherited. Lang has shown that inverse symmetry in the snail *Helix pomatia* may occasionally appear in normal dextral stock, but that sinistral parents almost invariably give rise to dextral forms; in general there seems to be no regular rule of inheritance of this character. It may be indeed that inverse symmetry is not inherited at all but is the result of environmental causes.

Therefore in the present state of our knowledge there is not sufficient evidence to conclude that modifications of the cytoplasm of germ cells are ever really inherited or that they are ever the initial steps in evolution.

2. *Modifications of Chromosomes*

We have already considered the evidences that the germinal organization which is primarily concerned in hereditary constancy or variation is found chiefly if not entirely in the chromosomes. Evolution therefore involves the problem of changes in the chromosomes or in the units which make up chromosomes, such as chromomeres and genes. Weismann maintained that germplasm must be in a high degree (*a*) stable, (*b*) distinct, (*c*) continuous. The chromosomal organization is more stable than the cytoplasm which undergoes many changes during ontogeny, while the chromosomes usually remain unchanged. The chromosomes being located within the nucleus and the nucleus within the cell-body are protected from extrinsic influences more than the cytoplasm. Furthermore they are relatively distinct from the cytoplasm and they are continuous from cell to cell and from generation to generation.

Undoubtedly modifications of chromosomal organization may and do take place. Only the grosser modifications can be seen directly, while many others must be inferred from physiological responses such as the results of development. Most of the visible changes which take place in chromosomes occur during mitoses while intermitotic stages are relatively more stable. Slight chemical, thermal or osmotic changes in the medium may produce extraordinary modifications of mitoses, whereas during resting stages changes many times as great may produce no visible or lasting effects. Almost all of the experimentally produced changes in chromosomes which are known to persist occur during mitoses, while those which are produced during intermitoses are, with one or two exceptions, relatively unimportant and temporary. This may be due to the fact that the chromosomes of mitotic stages are bodies which may be counted and in some cases individually identified, whereas during intermitoses it is difficult if not impossible to count or identify them. Since most of the visible modifications of chromosomes are seen as changes in their size, shape or number it is evident that these modifications could be seen only during mitosis. Many of these modifications are due to abnormalities in the division or separation of chromosomes and such abnormalities are necessarily limited to mitotic stages. Of course the chromosomes are not absolutely removed from the influence of external changes at any time but any influences that reach them during resting stages must come through the cell membrane, the cytoplasm and the nuclear membrane, whereas during mitosis the nuclear membrane is lacking. And in addition to this form of protection from external influences the chromosomes are more solid and consequently less easily changed than the surrounding plasma. But the principal reason why chromosomal changes occur during mitosis is to be found in the fact that the movements which accompany mitosis are interfered with so that division or separation of chromosomes does not take place normally.

Changes in resting nuclei due to the volume or quality of the cytoplasm or to chemical or physical changes in the medium are usually of a temporary nature and have no evolutionary significance. Variations in the volumes of chromosomes are dependent upon the volume of the resting nucleus and this upon the volume of fluid cytoplasm. These variations have no hereditary or evolutionary value as is evident from a comparison of the nuclei and chromosomes of ova and spermatozoa which differ greatly in volume but not in value.

Abnormalities in the conjugation (synapsis), separation (reduction) and distribution (equational division) of chromosomes are much more permanent and important. The two former occur only during the growth and maturation of the germ cells;[1] the last named may occur at any stage during the life cycle and in any cells of the organism, but if any abnormality is to affect the next generation it must be found in the "germ track" (germ-cell lineage). It is not surprising that modifications in the constitution or number of chromosomes are peculiarly liable to occur in the maturation stages in view of the fact that during these stages several complex processes occur which are usually lacking in ordinary mitoses. Among these are (*a*) synapsis or the union of homologous chromosomes from the two parents into pairs, the subsequent splitting of each member of a pair and the condensation of the four "chromatids" thus formed into one "tetrad" (Fig. 12, p. 274); (*b*) reduction or

[1] Metz has found that maternal and paternal chromosomes are paired in every mitosis in *Drosophila* and some other insects.

the separation of whole chromosomes of each pair and their movement to either pole of the mitotic figure (Fig. 17, p. 283); (*c*) the occurrence of two maturation divisions without the intervention of a resting stage by which the four "chromatids" of each tetrad are distributed to four different cells (Fig. 22, p. 389). As a matter of fact most of the persistent modifications of chromosomes which have been discovered hitherto appear during maturation stages.

(*a*) *Changes in Chromosome Number*.—The typical chromosome number may be more or less permanently changed and the developed organism may be greatly modified by non-disjunction of synapsed chromosomes, as Bridges has demonstrated (see p. 287). Probably many other cases in which the number of chromosomes and the characters of the developed organism are atypical may be caused by non-disjunction. For example it is known that *Œnothera lamarckiana* has typically 14 chromosomes in the zygote and 7 in the gametes, but the mutants *O. lata* and *O. scintillans* have 15 chromosomes (Gates, Lutz); the half-mutant, *O. semigigas,* has 21 chromosomes (Stomps), while the mutant, *O. gigas* has 28 (Gates). A likely explanation of the condition found in *lata* is that non-disjunction occurred in one pair of chromosomes of one gamete, whereas in *semigigas* it occurred in all the pairs of one gamete, and in *gigas* in all pairs of both gametes, and in this connection it is significant that *lata* has appeared many times, *semigigas* several times and *gigas* but twice.

Similar modifications of the typical number of chromosomes have been found in a considerable number of plants and animals. For example in *Ascaris megalocephala*, var. *univalens* there is 1 chromosome in each gamete and 2 in the zygote; in var. *bivalens,* which is otherwise indistinguishable from *univalens,* there are 2 in each gamete and 4 in the zygote. A similar case occurs in the sea-urchin *Echinus microtuberculatus* where 18 chromosomes are found in some individuals and 36 in others. The reduced number of chromosomes in a gamete is the *haploid* number; the usual number in a zygote is *diploid;* if an unreduced gamete and a reduced one conjugate the number is *triploid;* if two unreduced gametes unite the number is *tetraploid.* The triploid and tetraploid numbers are probably due to non-disjunction of all the chromosome pairs of one or of both gametes at the reduction division or to the failure of all the daughter chromosomes to separate in some of the ordinary divisions of the germ track. Both triploidy and tetraploidy have been repeatedly seen in many different plants and animals and in general they lead to gigantism, not only the entire organism being larger than normal but also the individual cells and nuclei.

It is well known that unusual chromosome numbers may result from hybridization of two forms having an unequal number of chromosomes. Thus Herla found that when the two varieties of *Ascaris megalocephala* were crossed, *univalens* having one chromosome in each gamete and *bivalens* two, the hybrid had three; and in all cases of hybrids the number of chromosomes in the zygote is the sum of those present in the two gametes. The same is true when more than one spermatozoon fertilizes an egg. Thus Boveri found that 54 chromosomes are present in a doubly fertilized sea-urchin egg, when each of the gametes contains 18 chromosomes. But since each spermatozoon brings into the egg a centrosome which quickly divides into two there is usually formed a four-poled spindle (tetraster) and the daughter chromosomes are distributed unequally to these four poles and to the four cells into which the egg divides. In general he found that those cells which contained a full haploid set of chromosomes developed normally while those which received less than a full set developed abnormally.

Spindles with three or four poles (triasters, tetrasters) and with double the normal number of chromosomes may result from the failure of the cell-body to divide following the mitotic division of the nucleus, and if centrosomes and chromosomes continue to divide while the cell-body remains undivided a great number of centrosomes (polyasters) and of chromosomes may be found in one cell. Whenever more than two centrosomes are present the chromosomes are almost certain to be unequally distributed to the poles of the mitotic figure, and to the daughter cells if the cell-body divides. Sometimes chromosomes are scattered along the mitotic spindle and do not move to its poles, so that when the daughter nuclei are formed these scattered chromosomes are left out in the cell and are ultimately lost. In all of these cases irregularities in the number of chromosomes are due to abnormalities of the mitotic apparatus by which the separation of daughter chromosomes is effected.

On the other hand variations in the number of chromosomes are not always due to non-disjunction at the reduction division nor to the failure of daughter chromosomes to separate in ordinary mitoses, as is shown by the fragmentation of the chromosomes of somatic cells in Ascaris, the pig and in *Œnothera scintillans* (Hance, p. 395), and also by the fusion of chromosomes into compound ones called by McClung "hexads," "decads," etc., as in some insects. In these cases it is certain that the unusual numbers are not due to non-disjunction but rather to a fragmentation or to a fusion of chromosomes. Metz has found that in different species of *Drosophila* the number of chromosomes varies from 6 to 12 depending, apparently, upon fragmentation or fusion of original chromosomes. In cases of fragmentation or fusion of chromosomes the quantity of chromatin and presumably the number of chromomeres remains the same. Consequently changes in the number of chromosomes caused by fragmentation or fusion represent merely changes in the grouping of chromomeres and not changes in the constitution of the hereditary material.

Abnormalities in the distribution of chromosomes of a cell persist in all its daughter cells and are not usually corrected. On the other hand abnormalities in the distribution of cytoplasmic substances to the cleavage cells frequently occur and usually the cell returns to a normal condition by a process of regulation. But when once the normal number of chromosomes has been changed there is no regular means of restoring that number. Momentary changes in the temperature, density or chemical composition of the medium may thus produce permanent changes in the distribution of chromosomes and of germplasm. Such changes in the distribution and number of chromosomes are usually of so gross a character that the development is not only very abnormal but also the resulting organism is incapable of continued life and reproduction. Consequently such changes do not usually give rise to new races or species; only in the most favorable cases where at least the full set of haploid chromosomes is present does the new form survive and reproduce.

Although abnormality in chromosome number is found in some mutants it is by no means certain that this abnormal number is the cause of mutation and there are some good evidences that it is not. For example, deVries finds that the tetraploid number in *Œnothera lamarckiana,* mut. *gigas* is a result rather than a cause of this mutation. *Gigas* is not merely a tetraploid *O. lamarckiana* but a true mutation in which the tetraploid number of chromosomes is one of the new characters. Stomps confirms this conclusion of deVries; he finds in *O. lamarckiana* and in *Narcissus poeticus* that the *gigas* condition may occur with or without doubling of the chromosomes; Gregory has found the same thing in *Primula sinensis.* Therefore in those *gigas* mutants in which the number of chromosomes is doubled we can not conclude that this is the cause of the mutation.

A similar condition is found in those animals in which the male has one less chromosome than the female; it has sometimes been assumed that the sex is caused by the number of chromosomes, and yet in many species the male and female have the same number, the sex chromosomes in one case being known as *XY* and in the other as *XX*. Morgan and his co-workers have shown that it is not the *number* of chromosomes which determines sex but the *kind* of chromosomes. This case bears directly upon the supposed relation between chromosome number and evolution, for the differences between a male and a female of the same species are frequently as great as those between two different species; indeed males and females might be regarded as mutants, were it not for the fact that both forms recur in every generation because of the recurrence of male and female chromosome combinations.

(*b*) *Changes in Chromosome Constitution.*—But just as sex differences are not always associated with a difference in the number of chromosomes, but often with differences in size or constitution of particular chromosomes, so mutants do not always nor even usually have different *numbers* of chromosomes though particular chromosomes probably differ in quality in different cases. Janssens discovered that chromosomes of a synaptic pair may twist around each other and he inferred that when they separate in the reduction division sections of the two may have interchanged places. Robertson and Wenrich have described a more complicated form of "crossing-over" due to a longitudinal splitting of each chromosome of a synaptic pair, the condensation of these four chromosomes into a tetrad and the subsequent separation of these in such a way that chromosomal interchange takes place. Morgan and his associates have shown that many important changes in the linkage of characters which are inherited in groups may be explained by this "crossing-over" of sections of homologous chromosomes (see p. 289).

But changes in chromosomal constitution are rarely directly visible, although they may be inferred from the results of development. By the study of Mendelian ratios Shull has shown that in certain cases a particular gene is duplicated in certain gametes. He points out that such "duplicate genes" could be caused by the synapsis of non-homologous chromosomes or by the transfer of part of one chromosome containing such a gene to another non-homologous one. In the former case the chromosomal grouping would be changed so that each gamete would contain two homologous chromosomes; according to his second hypothesis the *constitution* of two chromosomes would be modified, namely the one from which the gene in question was removed and the one to which it became attached. Bridges also has shown that there is genetical evidence that sections of one chromosome may in some cases be joined to another non-homologous one, and the cytological evidence shows that in certain cases chromosomes undergo fragmentations, in other fusions, and that a chromosome is not invariably composed of the same chromomeres. Bridges has described a phenomenon in *Drosophila* which he calls "deficiency" and which consists in the elimination (or inactivity) of certain closely linked genes, probably as the result of the dropping out (or the inactivation) of a section of a chromosome.

(*c*) *Experimental Modification of Chromosomes.*—Experiments on dividing cells show that chromosomes, like all forms of protoplasm, may be modified, injured or destroyed by various chemical substances, by increasing or decreasing the density of the surrounding medium, by increasing the temperature slightly above the optimum, by an electric current, X-rays, radium, etc. Such experimental conditions also cause very abnormal separation and distribution of the chromosomes in mitosis.

Such modifications of chromosomes either stop development altogether or they produce profound monstrosities which usually bring development to an end at an early stage. In few if any cases has it been possible to carry such abnormal forms to maturity and in no instance has any one been able to study the effects of such modifications of chromosomes on subsequent generations. Evidently experimentally produced modifications of chromosomes which are large enough to be visible with the microscope are usually too great to allow of their being carried over to another generation. However Plough has found that high temperature acting on the early oocyte stage of *Drosophila* increases the number of cross-overs and of course such changes are transmitted to subsequent generations; here is indirect evidence of the fact that the constitution of chromosomes may be modified and direct evidence that genetical constitution may be changed by environmental influences acting on the germ cells at an early stage. Probably many other changes in the constitution of chromosomes may be traced to environmental influences; if so initial stages in evolution may find their causes in such influences.

3. *Changes in Genes*

Although some inherited variations are caused by changes in whole chromosomes or visible portions of chromosomes, by far the larger number of such variations show no such visible causes. Nevertheless there is evidence that such variations are caused by changes in invisible units or genes which are located in the chromosomes. Reasoning from the seen to the unseen, from chromosomes to genes, we are justified in concluding that the behavior of the two is comparable, except that in general the simpler a unit is the more stable it is. Chromosomes are more stable than cytoplasm but genes are probably much more stable than chromosomes. We have seen that chromosomal organization may be modified: (1) by changes in number or combination due to the omission or addition of whole chromosomes, (2) by changes in constitution due to new combinations of the parts of which chromosomes are composed. It seems probable that genes also may be modified in these two ways.

(*a*) *New Combinations vs. New Constitution of Genes.*— The genetical evidence proves that entire genes may be transferred from one chromosome to another as in "cross-overs" or "duplicate genes" and that entire genes may be lost or rendered inactive as in "deficiency." In this way new combinations of genes are formed which lead to important changes in heredity and development and which may become initial stages in evolution. Furthermore it is highly probable that individual genes, in some cases, undergo a change in constitution owing presumably to fragmentation or new combination of the parts of which they are composed. In this connection it is interesting to recall that Darwin recognized two kinds of variations, (*a*) those caused by changes in the number of pangenes and (*b*) those caused by changes in the pangenes themselves ("Variations," Vol. II., p. 390). DeVries also made this distinction at an early date, in his "Intracellular Pangenesis" (pp. 73, 210). In the conception of deVries either of these changes are mutations; on the other hand Morgan and his school look upon mutations as changes in the constitution of individual genes, while new combinations of genes are not regarded as mutations in a strict sense.

The most important work on mutations and their causes has been done by deVries on the evening primrose, *Œnothera lamarckiana*, and by Morgan on the pomace fly, *Drosophila melanogaster*. In the former more than a score of mutants have been discovered and studied genetically, since 1900, in the latter more than 150 since 1910. Several geneticists, notably Johannsen, Heribert-Nilssen, Lotsy, Davis and Bateson, maintain that there is no sufficient evidence that *Œnothera lamarckiana* is a homozygous or pure form and they hold that the mutations described by deVries are the results of Mendelian segregation from this impure stock. This conclusion has now been demonstrated by Shull in the most satisfactory manner. The fact that such mutations occur only rarely and that they do not exhibit Mendelian ratios may be explained by the partial or complete sterility of certain gametes or zygotes, for in this genus there is much sterile pollen and many seeds fail to germinate. In *Drosophila* a large number of lethal factors have been discovered which cause the early death of zygotes in which they are not balanced by normal factors. In *Œnothera* also such lethals probably cause the death of certain classes of gametes and, if only those gametes which are different in the two sexes survive, the species will remain constantly heterozygous. In such a case if certain recessive factors are linked in the same chromosome with lethal ones they could come to expression only when by crossing-over this linkage was broken, and it seems probable, as Muller has said, that many mutants of *Œnothera* "are merely the emergence into a state of homozygosis, through crossing-over, of recessive factors constantly present in the heterozygous stock." Of the nine mutants of *O. lamarckiana* which were first discovered by deVries no less than five (viz., *lævifolia, albida, oblonga, rubrinervis* and *nanella*) are probably due to such cross-overs; three are possibly due to alterations in the usual number of chromosomes (viz., *lata, scintillans* and *gigas*) though the most recent work indicates that this is not the real cause of these mutations; while one (*brevistylis*) is evidently due to a change in a particular gene. If this interpretation is correct the *development* or appearance of all of these mutants depends upon a particular combination of dominant or recessive genes, though only in the last named mutant does this follow the rule of simple Mendelian segregation. But granting all this we explain only the peculiar manner of *segregation* of dominant and recessive factors in *Œnothera* and we find no explanation of the *origin* of such factors; the real problem after all is to explain how a dominant factor may give rise to a recessive one or *vice versa.* Here it seems logically necessary to assume that the individual factor undergoes some chemical or physical change. Peculiar combinations of dominant and recessive genes will explain the development of such mutants but not the origin of peculiar genes.

(*b*) *The Dogma of Immutable Genes.*—It is known that genes are relatively very stable; they may be carried along unchanged through hundreds of generations and thousands of individuals. Morgan calculates that there must be at least 7,500 genes in *Drosophila melanogaster* and yet in some hundreds of generations and many thousands of individuals he has found only about 150 mutant types although *Drosophila* seems to be mutating more rapidly than most species. The constancy of some species can be measured not only in years but even in geological ages and the constancy of some characters must be greater than that of a species, while the constancy of genes in general must be even greater than that of characters.

This relative stability has given rise to a dogma that genes are immutable and that all changes in the material basis of heredity are caused by new combinations of the same old genes; Lotsy in particular holds this view. It is interesting from the historical standpoint to recall that immutability has been ascribed to (1) species (Linnæus), (2) elementary species (Jordan), (3) pure lines (Lotsy), (4) unit characters (deVries), (5) germplasm (Weismann's earlier work), (6) genes (Lotsy). Immutability, like spontaneous generation, has sought refuge successively in smaller and smaller units but there is no reason to suppose that these smallest units of living matter are changeless. Indeed neither molecules nor atoms are now supposed to be absolutely changeless. In general the stability of any unit is proportional to its simplicity; no units of living matter are absolutely simple and therefore none is absolutely stable.

We know that species, subspecies, pure lines, persons, cells, chromosomes are subject to change. Genes are at the least very complex molecules and it is incredible that they are immutable or absolutely removed from influences of external or internal environment. The dogma of immutable genes leads logically to the position taken by Lotsy, namely, that there is no real variation, no actual evolution, no genuine progress; in short to a philosophical system of negations which is contrary to experience both in its assumptions and conclusions.

What are Genes?—As long as these units are not identified as material bodies it is possible to invest them with all the properties we are trying to explain and thus to shift the problems of heredity and evolution to a more inaccessible field. To a certain extent this has been done by Weismann and his followers. In all cases an "explanation" must be in more general terms than the thing to be explained.

Undoubtedly genes are material bodies with chemical and physical properties. Undoubtedly they are capable of growth and division like any other living units, though it is possible that they are not living in a strict sense. Their method of growth and division indicates that they are more than single molecules and are probably colloidal aggregates of molecules, though their great stability led Morgan at one time (1917) to suggest that they might be single molecules. The fact that they have the power of growth and division suggests that they are autocatalytic substances (p. 276) and their great influence on development in spite of their very small size, as well as their specificity, has suggested to several writers that they are enzymes or bodies which produce enzymes.

(*c*) *Mutation of Genes.*—The fact that genes are relatively complex bodies would indicate that they can not be absolutely stable and wholly uninfluenced by environment, for nothing can be such which is not absolutely simple. Assuming then that genes are at least very complex molecules of protein-like substance and that more probably they are colloidal aggregates of such molecules, we may conclude that they undergo change by dissociation and recombination of the molecules, radicals or atoms of which they are composed. With large and complex molecules enormous numbers of different combinations of the same atoms are possible; thus Miescher calculates that a molecule of albumin with 40 carbon atoms may have as many as one billion stereo-isomers, and in protoplasm there are many kinds of albumin and other proteins, some with more than 700 carbon atoms. Reichert says that serum albumin may theoretically exist in as many as a thousand million forms. Therefore, even if genes are single molecules, it is chemically possible to have an enormous number of variants of each of them, and if they are aggregates of such molecules the number of different kinds which would be chemically possible would be greatly increased. Mutation in genes may therefore be thought of as due to the loss or addition of certain constituent atoms or molecules or to the rearrangement of some of these. But on the other hand the fact that genes are relatively very stable indicates that something other than the possibilities of chemical alteration are involved in their mutations.

It is an interesting fact that many mutations seem to involve the loss of something; very many if not the majority of the mutations which have occurred among domestic animals and cultivated plants are of this sort, such as the loss of color (albinism) in many plants and animals, the loss of glumes or bristles or hairs, etc. Such mutations deVries calls "regressive." On the other hand a few mutations seem to add something which was not present before and these deVries calls "progressive" and he thinks that they are of especial significance in evolution. We must not however conclude that the loss or addition of a character means the loss or addition of a new gene nor even of molecules or atoms of a gene, for the rearrangement of the parts of a gene may lead to the appearance of new characters just as the rearrangement of the atoms of a molecule may lead to new qualities in a chemical substance. The old idea of evolution by addition of new characters, or by accretion, is out of harmony with what we know of individual development where differentiation takes place by the transformation of units already present and not by additions of new units. Nowhere in the entire process of organic evolution is there any evidence that new genes are "extrinsic additions" or are created *de novo*. When Morgan says: "Evolution consists largely in introducing new factors that influence characters already present" (1917) he can only mean that new combinations of the same old genes are brought about by crossovers, non-disjunction or fertilization, or that new kinds of genes arise by transmutation of old ones through new combinations of the elements of which genes are composed. The whole mechanism of evolution consists in new combinations of the units of organization whether those units be characters, cells, chromosomes, chromomeres, genes, subgenes, molecules or atoms.

Mutants are in the main recessives when mated with their normal allelomorphs, but they are not always recessive as is claimed by Lotsy. Among more than 150 mutants which have appeared in Morgan's cultures of *Drosophila* 12 are dominant or semi-dominant. Many other dominant mutants are known such as abnormally short limbs, fingers and toes, supernumerary digits, hereditary cataract and other eye defects in man, hornlessness in cattle, rumplessness in poultry, red sunflowers, red buds in *Œnothera lamarckiana, mut, rubricalyx, et al.*

Morgan and his school have proved by genetical evidence that a particular gene may change in any one of several different ways, probably owing to various changes in its composition. Thus the gene for the normal red eye color may change so as to give rise to "blood," "cherry," "eosin," "buff," "tinged" or "white" eyes. Genes, or allelomorphs, that mutate in various directions give rise to what are known as "multiple allelomorphs"; hypothetically these may be explained as due to different changes, probably of a chemical nature, in a particular gene. Not only may genes mutate in different directions but some genes apparently mutate more frequently than others, as Emerson has shown in the case of corn and as Morgan has found in *Drosophila*. DeVries especially has long maintained that some genes are more "labile" than others, although more recent work on *Œnothera* indicates that this so-called lability may be caused by crossing-over, at least in some instances.

Furthermore the same mutation may occur independently in different cultures or even in different species. Thus Morgan says that white eyes have appeared independently in his cultures of *Drosophila* three different times, vermilion eyes six times, rudimentary wings five times, etc. In this case it is known that the mutating gene in each instance named occupies the same locus in the chromosomes and there can be no doubt that each of these recurring mutations is due to the same sort of change in the same gene. DeVries has observed the independent recurrence of the same mutation in different cultures of *Œnothera,* and other investigators have noted a similar phenomenon in other organisms; these are probably caused by identical changes in particular genes. The independent recurrence of a mutation must indicate a tendency for a gene to change in a particular way just as chemical changes tend to go in certain directions. A similar cause probably underlies the tendency of organisms to evolve in definite directions—a phenomenon which has been called "orthogenesis" (Haacke, Eimer, Whitman) and which has been especially emphasized by paleontologists.

Not only do the same mutations recur within the same species but apparently identical mutations may appear within different species. Metz has shown that certain mutants of *Drosophila virilis* closely resemble corresponding ones in *D. melanogaster* and that in both species the mutating genes are located in corresponding chromosomes; however such cases are exceptional. Albinism, melanism, gigantism, etc., have appeared repeatedly in many different species, and this raises the interesting question whether identical genes may occur in different species and undergo identical changes. While this may be true in some cases it is certainly not true in all. Mutations which look alike may be genetically different; albinism, for example, is recessive in mammals while at least two kinds of albinism occur in poultry, one of which is dominant and the other recessive. White flowers even within the same species may be due to mutations in different genes, as in the case of sweet peas; Morgan has shown that mutants of *Drosophila* which look alike may be caused by mutations of different genes, occupying different loci in the chromosomes. We can not conclude, therefore, that mutations which look alike are always due to similar changes in identical genes.

Mutations of genes may probably occur in any cell, but if they are to be transmitted to the next generation by sexual reproduction they must take place in the germ-cell lineage at least as early as the maturation stages in the case of dominant or sex-linked characters and possibly much earlier, while in the case of recessive mutations they may occur many generations back and be carried along without giving any sign of their presence until they are mated with a similar recessive muta-iton. In such cases the actual mutation occurs long before it comes to expression in a developed mutant.

(*d*) *Extrinsic Causes of Mutation.*—Various changes in the chemical and physical environment produce abnormalities in the number, distribution and constitution of chromosomes, as was pointed out on a previous page, and it is not antecedently improbable that such environmental changes may produce similar modifications in genes themselves. Nevertheless it must be admitted that at the present time no single case is known in which such environmental changes have certainly produced a mutation in a gene.

Several investigators have described cases in which mutations have been ascribed to the action of external agencies, but in no one of these cases is it certain that the external change produced the mutation in question. One of the first instances of the supposed experimental production of a mutation was described by MacDougal in 1905. He reported that he had injected various solutions, particularly zinc sulphate in different concentrations, into the ovaries of a species of *Œnothera* (*Raimannia*) and had obtained as many as 13 different mutants. A year later he reported that he obtained 3 mutants in a similar way. These results have not been confirmed by other workers and the evidence seems to favor the view that MacDougal was dealing with a naturally mutating stock and that the mutants were not caused by the experimental conditions.

Tower (1906) carried on extensive and prolonged studies on the evolution of the potato beetle, *Leptinotarsa*, and concluded that he had induced mutations in this form by changes in humidity and temperature acting upon the germ cells at a sensitive stage in their genesis, presumably by causing mutations in the genes. But in this case also it is not certain that the mutations observed were actually caused by the experimental treatment and there are many reasons for concluding that they were not.

Many other investigators have studied the injurious effects on development of different experimental conditions acting on the germ cells. Thus Bardeen and O. Hertwig found that when normal frog's eggs were fertilized by spermatozoa which had been exposed to X-rays or radium the resulting development was very abnormal. Cole found that when lead acetate was fed to rabbits or fowls their germ cells were so affected that they produced abnormal offspring. However in none of these experiments is it known that these abnormalities were heritable, since they were not followed to later generations.

Stockard has made an extensive study of the inherited effects of alcohol upon guinea pigs. He finds that the offspring of alcoholized animals are frequently weak and abnormal and that these effects may be traced to the third or fourth fillial generation. The effects of alcohol on the male germ cells seems to be greater than on the egg cells, and since the portion of the spermatozoon which enters and fertilizes the egg is composed almost entirely of chromosomes it seems reasonable to conclude that the chromosomes have been injured by the alcohol. On the other hand there is no evidence here that individual genes have been caused to mutate and the fact that the injurious effects wear off after three or four generations seems to indicate that the changes produced by the alcohol are not of the nature of mutations. It should be said that Pearl's experiments on the inherited effects of alcohol on chickens do not support Stockard's results; he finds that the offspring of alcoholic parents are fewer in number but stronger than those from normal parents and he concludes that the effect of the alcohol is to kill the weaker germ cells and embryos and to permit only the more hardy ones to survive.

In these experiments with alcohol there is no evidence that genes have been caused to mutate, and indeed there is no satisfactory evidence that the defects observed in the offspring of alcoholic guinea pigs were really inherited. It is known that many environmental influences, such as food, temperature, soil, etc., may modify the development of the first and even the second succeeding generation and then disappear, as Whitney has shown in the case of Rotifers, Woltereck in *Daphnia* and Harris in beans. Such temporary modifications are not really inherited and are known as "induction" phenomena. They do not represent modifications in heredity but rather in development, not mutations in genes but possibly alterations of the cytoplasm.

In conclusion it may be said that although it is certain that mutations of genes take place and although it is highly probable that these mutations, like all chemical and physiological processes, are affected by environmental conditions, nevertheless we do not know what the conditions are which induce mutations and at present we are unable to initiate or control them.

(*e*) *Intrinsic Causes of Mutation.*—The failure to find definite extrinsic causes of mutation has led certain students of the subject to conclude that all changes in genes are due to intrinsic causes. The gene has been compared to the radium atom which undergoes disintegration wholly uninfluenced by temperature or other physical or chemical conditions. But, as has been indicated, the gene is not an atom but at the very least an extremely complex molecule and it is incredible that it should be wholly removed from environmental influences, since this is true of no other molecule or group of molecules.

We have no more direct knowledge regarding the intrinsic causes of mutation than concerning the extrinsic ones and yet we may safely assume that certain general principles which apply to visible portions of the organism are true of invisible genes. As development or any physiological process is the response of an organism to various stimuli, so we may assume that mutations also represent the response of the hereditary organization to certain stimuli; and just as the nature of any response is primarily determined by the nature of the organism while the stimuli serve merely to initiate, hasten or retard the response, so the nature of a mutation is probably definitely limited by the organization of the germplasm while its extrinsic causes serve only to initiate or retard it. With true insight Charles Darwin wrote many years ago:

> Although every variation is either directly or indirectly caused by some change in the surrounding conditions, we must never forget that the nature of the organization which is acted on essentially governs the result.

Some conceivable mutations never become real because of these intrinsic limitations. "Whales never produce feathers, nor birds whale bone," said Huxley; and probably no one ever really saw a green horse or a purple cow.

Mutations can not therefore take place in all conceivable directions, owing to the limitations of the organization of the germplasm and these same limitations may sometimes cause mutations to follow more or less closely in particular lines, as for example in the independent recurrence of the same mutation, but on the other hand the organization of a gene is so complex that it may undergo many different alterations, as is shown in cases of "multiple allelomorphism." There is no justification therefore for extreme views of orthogenesis which regard mutations as taking place only in a single direction.

Another hypothesis which is the result of a too extreme insistence on the intrinsic factor of mutation is found in the view that all mutations of genes are in the nature of losses or disintegrations more or less comparable to the disintegrations of the radium atom. The "presence and absence" hypothesis assumed that dominant characters are due to the presence of a factor and recessive character to its absence, and since regressive mutations, in which some dominant character becomes recessive, are much more numerous than progressive ones, it was suggested by Shull, Bateson and Davenport that evolution might be due to the loss or disintegration of factors or genes. "This conception results," said Shull (1907), "in an interesting paradox, namely the production of a new character by the loss of an old unit," and he suggests that at least the later stages of evolution may be a process of analysis due to the disappearance of one unit after another. Bateson (1914) also proposed the same thing in his well-known inquiry "whether the course of evolution can at all reasonably be represented as an unpacking of an original complex, which contained within itself the whole range of diversity which living things present"; and in the same category is the speculation by Davenport that "the foundations of the organic world were laid when a tremendously complex molecule, capable of splitting up into a vast number of simpler molecules, was evolved." But the speculation that a recessive character is due to the absence of a factor has been disproved by work on multiple allelemorphs for here although there may be several kinds of recessives to the same dominant allelemorph there can be only one kind of absence. Furthermore this hypothesis of evolution by degredation offers no real explanation of evolution, but like the old doctrine of preformation it merely puts the mystery back into the supposed causes.

But apart from the fact that this hypothesis of evolution by disintegration offers no real explanation of evolution, it does not at all conform with what we know of other natural phenomena. In the inorganic world, as well as in the organic, changes involve not merely breaking down but also building up, not merely analysis but also synthesis. Everywhere in the living as well as in the lifeless world disintegration is balanced by reintegration. Chemical changes are the results not only of dissociation but also of recombination. In embryonic differentiation new structures and functions arise not merely by a process of disintegration of the structures and functions of the egg and a sorting out of these fragments to different cells, but also by the transformation of the germinal structures and functions into those of the developed organism by a process of recombination or "creative synthesis." Similarly in phylogeny new types, new characters, new genes, arise by the transformation of those already present by a process which may be called "creative evolution."

In conclusion we find that it is impossible to avoid the conviction that the initial stages in evolution are caused by new combinations of chromosomes, chromomeres, genes or subgenes, and that these new combinations take place in response to stimuli from the external or internal environment. Probably experimental cytologists have already made many such new combinations which might have given rise to new species, genera or even phyla if they could have survived. Unfortunately almost all of these changes in the germplasm have been of so gross a character that the new forms were unable to live beyond the early stages of development, and the more extreme they were the earlier they perished. Germ cells are so complex and are so delicately adjusted and balanced that they can not usually be greatly changed without rendering them incapable of continued life. Experimentalists have aimed to produce changes in germ cells or embryos which could be seen with the microscope, but it will be necessary to produce smaller and more subtle changes in the germplasm if we are to determine their effects on succeeding generations. The future may show us methods of modifying the germplasm, more delicate and effective than any that have been discovered as yet, and when that time comes, if it ever comes, a real experimental evolution will be possible.

The mystery of mysteries in evolution is how germplasm ever became so complex as it is, so well adapted to give rise to viable organisms, so filled with the marvellous potencies of development. The greatest problem which confronts us is no longer the mechanism of evolution but the evolution of this mechanism. This problem has been shifted from the developed organism to the germplasm, but has not been solved.

STATE PARKS IN IOWA

By Professor L. H. PAMMEL

IOWA STATE COLLEGE

THE thirty-seventh general assembly of Iowa passed a comprehensive state park bill in the following section of the law:

> The State Board of Conservation, by and with the written consent of the executive council, is hereby authorized to establish public parks in any county of the state, upon the shores of lakes, streams or other waters of the state, or at any other places which have by reason of their location become historic or which are of scientific interest, or by reason of their natural scenic beauty or location become adapted therefor, and said Board of Conservation, under the supervision of said executive council, is hereby authorized to improve and beautify such parks. When so established they shall be made accessible from the public highways, and in order to establish such parks said executive council shall have the power to purchase or condemn lands for such purposes and to purchase and condemn lands for such highway purposes.

The law also provided that the state executive council designate three persons, who with the curator of the Historical Department shall constitute a Board of Conservation, who shall serve without pay. The original bill provided that the sum of $50,000 be appropriated annually out of fees obtained from hunters' license fees. The thirty-eighth general assembly amended this section by making an annual appropriation of $100,000 annually. Thus there came into being a constructive movement for the preservation of regions of historical, scientific and recreational interest.

This movement was of slow growth. More than a quarter of a century ago Dr. Thomas Macbride, of the State University of Iowa, in an address before the Iowa Academy of Science advocated a system of county parks distributed throughout the State; subsequently the Iowa Park and Forestry Association which later became the Iowa Conservation Association, at repeated annual meetings asked the legislature to conserve some of the natural beauty of Iowa. The state park measure has found a hearty response in all parts of the state. The hearty response comes, not only from the cities, but the rural population as well. I like to look upon this movement as a rural movement, because Iowa is essentially a great rural agricultural state. There are no large centers of population. Less than a

View of the Maquoketa River in Backbone Park, Delaware County. (Photographed by I. Bode.)

half dozen cities have a population of over 50,000, and only one city has a population of over 100,000.

Those who ride over the state on any of the great transcontinental railways think of Iowa as a state of rolling prairies, devoted to the cultivation of corn and oats, and pastures where fine herds of cattle and sheep graze on the rich bluegrass. Here and there, as the trains cross the valley, one may see small belts of timber. The timbered area is, however, larger in northeastern and southeastern Iowa. Iowa was the center of various ice invasions: the Kansan, Iowan and Wisconsin and a few other minor invasions. These ice sheets shaped the topography of the state, and left the imprints of the floristic features of the region. Let us for a moment consider the most recent of the ice invasions; the Wisconsin, entering the state in Worth county on the east and Osceola county on the west, culminated in Polk county. In this region occur seventy or more lakes, none large, and most of them shallow, with the exception of Lake Okoboji, which is one of the most beautiful lakes in the northern Mississippi valley. In the same county and to the north occurs Spirit Lake, covering a good many hundred acres. In a half dozen counties to the east are many other fine lakes, but all are comparatively small. Curiously enough such lakes as exist in the southern portion of the Wisconsin drift also occur in a tier of counties, to the north of Story, including Hamilton and Sac counties. There were formerly a few very shallow lakes in counties in the same latitude with Story county, one of which, Goose Lake, is so shallow, that it has been ordered drained.

Two Hundred ane Fifty Year Old White Pine on the Maquoketa River in Backbone Park in Delaware County. (Photographed by I. Bode.)

In our park system it is hoped to buy areas on the shores of all of the lakes to conserve the animal and plant life and give people generally a chance to make use of these bodies of water. To-day the public can not have access to the lakes, except as trespassers. In the prairie region where these lakes occur there is usually some timber. The state proposes to secure some of these areas. Parks established at these places will be designated lake parks.

Woods along the Upper DesMoines River near Estherville.

A second kind of park to be established will be state parks, such parks to contain large areas along our streams. The first one of these parks to be established, the Backbone Park in Delaware county, contains 1,200 acres. It is situated on the Maquoketa River. The river here has cut through limestone rock more than 100 feet thick. At a point known as the Backbone, or as the old settlers called it, the Devil's Backbone, is a narrow ridge in some cases not more than 50 feet across with the river flowing on each side of it. This park contains some of the original pine trees, some of which are nearly three feet in diameter, and one hundred and sixty to one hundred and seventy years old, some at least two hundred and fifty years old. Growing with the pine are white, chestnut, red, bur and black oaks.

A second park of 1,123 acres has been established in Van Buren county in southeastern Iowa, in a region known as the Horseshoe Bend. This area contains great white oaks 3½ feet in diameter, swamp, white and red oaks. Various forms of animals found in Iowa occur here, like the native pheasant, or drumming partridge, now a rare bird in Iowa; the opossum, the fox, and quail which are found in abundance.

A third park of small dimensions has been established in Henry county on the Skunk River. This park contains some of the primeval sugar maple (*Acer saccharum*), great sycamores and hackberries.

Ledges in Boone County, along the DesMoines River, Sandstone Cliffs 125 Feet High. (Photographed by C. M. King.)

There are under consideration projects for reserves in Boone county in an area known as the "Ledges." These sandstone ledges contain the carboniferous sandstone common along the Des Moines from Webster county south in what is known as the Cedar Bluff region in Mahaska county This area contains an interesting lot of rare ferns.

A Wooded Slope near Kellerton, in Ringgold County, Southwestern Iowa.

There is also under consideration an area in Webster county, known as Woodman's Hollow and Bone Yard Hollow. In Hardin county we have another interesting region known as the Steamboat Rock, Eldora and Alden region. At Steamboat Rock we have not only the most westerly distribution of the white pine, but an abundance of the cherry birch (*Betula lenta*) and the paper birch. The large white lady slipper occurs on the steep slopes of the clay hills.

Two sisters, Misses Clara and Emma Brandt gave to the State 57 acres on Pine Creek in Muscatine county, known as Wild Cat Den. Here may be found such ferns as *Aspidium Goldianum, Phegopteris hexagonoptera, Polypodium vulgare, Pteris aquilina, Pellaea atropurpurea, Camptosorus rhizophyllus, Woodsia obtusa, Osmunda struthiopteris, Onoclea struthiopteris* and *Cystopteris bulbifera.* The region has been protected largely because these two nature-loving women saw the wisdom of keeping for posterity the beautiful things of nature.

There is also under consideration an area in Jackson county, known as Morehead caves, where a natural bridge, which though not as large as the natural bridge of Virginia, rivals it in beauty. Hanging from the walls of the limestone rock are great masses of *Sullivantia ohionis, Cystopteris fragilis* and *C. bulbifera.* The cliff brake *Pellaea atropurpurea* was abundant everywhere on the dry limestone rock.

Another area under consideration is the Yellow River area in Allamakee county. This area contains not only the white pine and balsam fir, the latter a very rare tree in Iowa, some two hundred miles out of its range, but many other boreal plants like the little white violet (*Viola blanda*), the high bush cranberry (*Viburnum opulus*), Enchanter's night shade (*Circaea alpina*), *Phegopteris calcarea, Aconitum noveboracense,* paper birch, sweet birch (*Betula lenta*) and speckled alder (*Alnus incana*) and the yew (*Taxus canadensis*).

Another area under consideration occurs in what is known as the Palisades in Linn County. Great primeval white oak, the walking leaf fern (*Camptosorus rhizophyllus*), yew, leather wood (*Dirca palustris*), occur in this region. A lot of fine Indian mounds are found here. The state hopes it may place all of these Indian mounds in state parks and Iowa is especially rich in mounds.

In writing about state parks, I should not forget to mention that it is proposed to have a national park or monument on the great and majestic Mississippi River at McGregor, which we hope, will contain several thousand acres and be linked up with our state parks at Waterville, Decorah and the Yellow River. It is far-sighted wisdom that the state of Iowa establish these state parks to preserve to future generations the natural history, geology, and historic features of Iowa.

We also propose to establish highway parks of smaller extent, one or more of these in each county, to be located near some stream, which will serve to preserve the woods, wild flowers, birds and game. We will also consider prairie areas where the wild prairie flowers and animals will be protected.

THE PROGRESS OF SCIENCE

THE NORTHUMBERLAND HOUSE OF JOSEPH PRIESTLEY

Joseph Priestley, born in Yorkshire in 1733, was by profession a dissenting clergyman and carried on his work in science as an amateur. He was led in part by association with Franklin to take up the writing of a history of electricity and to make original experiments in connection with this work, in recognition of which he was elected to the Royal Society and awarded its Copley medal. His remarkable work on gases was carried on while he was acting as a unitarian clergyman at Leeds and Birmingham. He not only discovered oxygen, but also sulphuric and muriatic acid, and did much to enlarge knowledge concerning the properties of oxygen, nitrogen and other gases.

Priestley was not only a liberal in religion, opposed to a state church, but advocated democratic principles of government, with freedom of thought and liberty of discussion. At the time of the French revolution he was made a citizen of France and a member of the assembly. This led to persecution at home, and on the anniversary of the French revolution, in 1791, there was a riot in Birmingham, in which his meeting house and dwelling were burned, and his manuscripts, library and apparatus destroyed. He was even obliged to withdraw from the Royal Society.

Under these conditions Priestley sought freedom in the United States where his sons had already preceded him. Arriving here in 1794, he was received with distinguished consideration by Jefferson and others, the American Philosophical Society presented him with a complimentary address and the University of Pennsylvania offered him a professorship of chemistry. It is said, however, that the alien and sedition law of the Adams administration was

The Priestley House at Northumberland.

THE PRIESTLEY HOUSE.

passed with some reference to him, and Mr. Adams warned him to abstain from saying anything on politics lest he should get into difficulties.

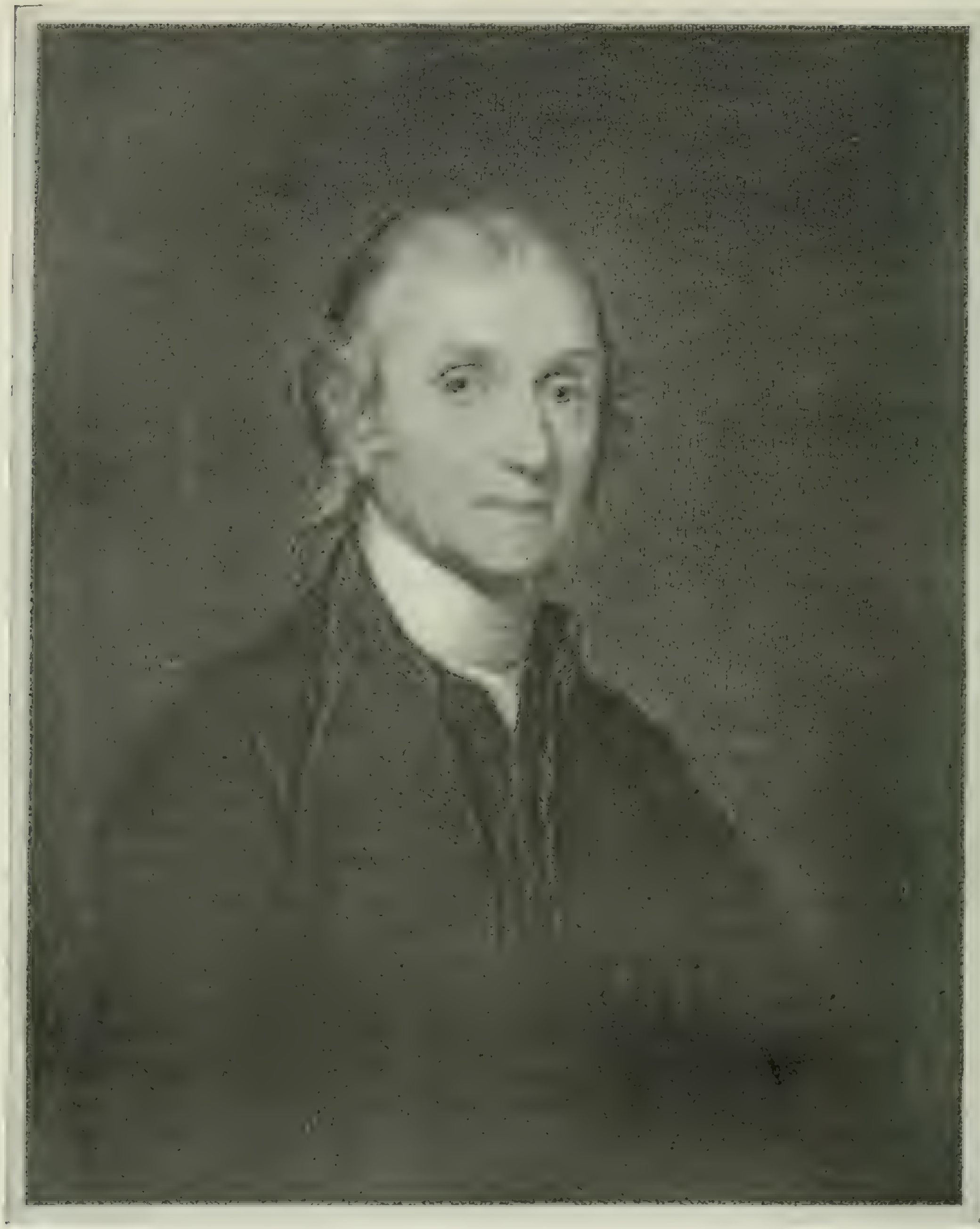
Priestly retired to Northumberland on the Susquehanna river one hundred and thirty miles from Philadelphia, where the house shown in the accompanying illustrations, gave him a library and laboratory. There he worked until his death in 1801.

This Priestley homestead was purchased recently by graduate students of the Pennsylvania State College, who plan to move it to the campus and make it a lasting memorial. Upon learning that the house which was built in 1794–1796, was to be put up at public auction, the Penn State chemists sent as their representative to the sale Dr. G. G. Pond, dean of the School of Natural Science at the college. He was sucessful in making the purchase, and the historic mansion will be preserved.

Architects from the college will make the necessary surveys preparatory to the work of moving the Priestley house to the campus at State College. The house is of frame, and painting has kept the woodwork in a remarkable state of preservation, so that it may be possible to rebuild the greater part of the structure from the present lumber. Immense pine timbers used in the framework are as good as new and the old-fashioned interior decorations—arched doorways, fireplaces and stairway—are in such condition that they can be removed and replaced with comparative ease.

While the purchase of the house has been made for the Penn State chemistry alumni, who are scattered to all parts of the country, funds for its removal and erection on the college campus will be supplied by an as yet unnamed donor. Actual work of removal will probably be started soon. Northumberland is about sixty miles from State College, at the intersection of the north and west branches of the Susquehanna.

The reconstruction on the college campus will be along the old architectural lines, but modernized and adapted to some suitable use by the school of Natural Science, according to present plans. The house is an old landmark in Northumberland county, and can be seen on the



JOSEPH PRIESTLEY.

outskirts of the town from trains on the Pennsylvania Railroad passing Northumberland. It is a two-story structure, with capacious attic space. It is about 45 × 50 feet, with a projection at each end about 25 feet square. One of these was the kitchen and the other the workshop, or laboratory, in which Priestley pursued his scientific study and experiments.

THE WORK IN INDUSTRIAL CHEMISTRY OF THE AMERICAN CHEMICAL SOCIETY

A GROUP of chemists met at Northumberland in 1874 to celebrate the one hundredth anniversary of the discovery of oxygen by Priestley and from this meeting the American Chemical Society had its origin. The society, which now has some 14,000 members and publishes three important journals, held its spring meeting at St. Louis in April. From a technical point of view the meeting was one of the most helpful and practical ever held by the society. Well-known chemists, who had been active in war work, reported the first fruits of their researches, made since their return to the university and the commercial laboratories. These constitute important contributions to industry and also to the general welfare of the American people.

Several sections of the society dealt with the reduction of the high cost of living in its various phases. The search for vegetable substitutes for meat was shown in papers describing the proteins found in pecans and in Georgia velvet beans. The growing importance of the American beet sugar industry was revealed in a paper on its chemical control. The nature of that invisible and illusive power represented by the vitamines, which are so essential to the quality of food and are destroyed in stale and over-cooked viands, was discussed in papers indicating that the day is at hand when they may be isolated and administered.

Suggestions for the hardening of vegetable oils with the aid of catalyzers, substances which alter the nature of liquid fats through chemical reaction, point the way to the further development of butter substitutes.

The soft drink industry, which has increased greatly in this country, is making an extensive use of lactic acid, usually derived from sour milk and also obtainable from other sources. The acid is formed by those benevolent bacteria present in the Bulgarian sour milk drinks made famous by Metchnikoff as a means of prolonging life. The use of edible lactic acid and in the potations prohibition has popularized, such as ginger ales and kickless beers, would thus tend to prolong the span of life.

Many persons have come to an untimely death through the drinking of wood alcohol served by bootleggers and unscrupulous dealers, and to shield the public from excess it was proposed before the Pharmaceutical Section that the dangerous liquid be deprived of the name "alcohol" entirely and, following a practise already begun, be known merely as "methanol."

The slogan, "Use American Potash" was sounded by a representative of the United States Department of Agriculture, which is endeavoring to bring this fertilizing element within the reach of every farmer. Experts reported that the American industry need have nothing to fear from the German potash companies which once practically monopolized the trade. The element is now being obtained in considerable quantities as a by-product of the making of cement. The announcement was also made that so many were the by-products obtained in the making of potash from kelp, a giant seaweed plentiful along the Pacific coast, that the kelp-potash industry, with which the government has been experimenting, can now be developed on a profitable basis.

Several papers were read on the feeding of live stock in which suggestions were offered for making the alfalfa, various grasses, silage, and also peanuts more available for animal food.

The extensive experiments made by the Chemical Warfare Service in the preparation of a charcoal rendered porous or activated for use as an absorbent for noxious vapors in the army gas masks, have borne fruit in the development of new industrial uses for this treated material. What with the adapting of the war gas mask for the service of manufacturing and mining, the Chemical Warfare Service, as described in a public lecture given by its head, Lieutenant-Colonel Amos

JOHN ALFRED BRASHEAR

Distinguished as a maker of astronomical and physical instruments and an astronomer, a leader in the scientific, educational and civic life of Pittsburgh, who died on April 9, in his eightieth year.

A. Fries, has made many important contributions to the arts of peace.

The newly constituted Leather Section of the society developed improved processes in the tanning of hides for shoes and for industrial purposes which are likely to greatly increase the efficiency and speed of tanning processes and possibly contribute to a decrease in the prices of footgear. The section devoted to rubber considered a new method of testing that elastic substance with the microscope which is considered revolutionary.

American dyes are able to hold their own not only for the tinting of fabrics but also for scientific and medical purposes, as demonstrated by important papers read before the dye division. A new note appeared in the proposal to derive from corn cobs furfural, which may be used as a base from which to draw dyes, just as certain coal tar products are employed. Thus, furfural green, a favorite tint, may eventually be derived from the refuse of native maize.

MEAT AND MILK IN THE FOOD SUPPLY

THE committee on food and nutrition of the National Research Council has issued a report on meat and milk in the food supply of the nation, which is summarized in a press bulletin of the council.

Dr. Armsby, probably the leading American expert on animal nutrition, has estimated that of the energy of grain used in feeding the animal there is recovered for human consumption about 18 per cent. in milk, and only about 3½ per cent. in beef. In an official Report on the Food Supply of the United Kingdom, it is estimated that the production of 100 calories of human food in the form of milk from a good cow, requires the consumption of animal feed by the cow of 2.9 pounds starch equivalent; 100 calories milk from a poor cow is estimated to require the consumption of 4.7 pounds; while 100 calories of beef from a steer 2½ years old, is estimated to require the consumption of 9 pounds of starch equivalent in food.

Stated in terms comparable with those used by Dr. Armsby, this would mean that the good milk cow returns 20 per cent. of the energy value of what she consumes, the poor milk cow 12 per cent., and the good beef steer only 6 per cent. Although this estimate is more favorable to the beef steer than is that of Dr. Armsby, yet even by this estimate it will be seen that the poor cow is twice as efficient, and the good milk cow more than three times as efficient as the beef steer in the conservation of energy in the food supply.

Considering the whole length of life of the animal, Professor Wood, the leading English agricultural expert, estimates that the cow returns in milk, veal and beef, $\frac{1}{12}$ as much as she has consumed, while the beef steer returns only $\frac{1}{64}$. In other words, the cow is five times as efficient as the beef steer as a food producer when the whole life cycle of the animal is considered.

Similarly it has been estimated by Cooper and Spillman (Farmers Bulletin, No. 877, 1917, U. S. Department of Agriculture) that the crops grown on a given area may be expected to yield from four to five times as much protein and energy for human consumption when fed to dairy cows as when used for beef production. As Professor Wood has very strikingly shown, the longer the time that the beef animals are fattened on grain, the less economical the process becomes.

But not only is the milk cow several times more efficient than the beef steer in the conservation of proteins, fats and carbohydrate for human consumption, but in the gathering and preparation of mineral elements and vitamines she contrasts even more favorably with the beef animal. It is largely because of its richness in calcium and in fat-soluble vitamine that milk is the most efficient nutritional supplement to bread or other grain products.

SCIENTIFIC ITEMS

We record with regret the death of George Egbert Fisher, professor of mathematics in the University of Pennsylvania; James Gayley, past president of the Institute of Mining Engineers; James Emerson Reynolds, formerly professor of chemistry at the University of Dublin; Charles Lapworth, for many years professor of geology and physiography in the University of Birmingham; Pier Andrea Saccardo, emeritus professor of botany in the University of Padua, and Woldemar Voigt, the mathematical physicist of the University of Göttingen.

At a meeting held in the rooms of the Royal Society, to consider the question of a memorial to the memory of Lord Rayleigh, it was agreed that a fund should be raised for the purpose of placing a memorial, preferably a window, in Westminster Abbey. A committee was appointed to consider details and the further question of raising a fund in memory of Lord Rayleigh, to be used for the promotion of research in some branch of science in which he was specially interested.—Dr. Harvey Cushing, Peter Bent Brigham Hospital, Boston, has been requested by

Lady Osler to prepare a biography of Sir William Osler. He will be grateful to any one who will send him either letters or copies of letters, or personal reminiscences, or information concerning others who might supply such information.

THE University of Pittsburgh has conferred honorary doctorates upon Dr. William H. Nichols, retiring president of the American Chemical Society, and Dr. William A. Noyes, present president.

SIR JAMES DEWAR has been elected a corresponding member of the French Academy of Sciences in the section of physics in succession to the late Professor P. Blaserna.

THE National Research Council has appointed a committee on eugenics, under the division of biology and agriculture with Dr. C. B. Davenport, as chairman, and this committee has voted to hold the Second International Eugenics Congress in New York City, September 22 to September 28, 1921 on the invitation of the American Museum of Natural History Dr. Alexander Graham Bell has been elected honorary president and Dr. Henry F. Osborn, president.

PROFESSOR ALBERT A. MICHELSON, of the University of Chicago, has been elected a foreign associate of the Paris Academy of Sciences to succeed the late Lord Rayleigh.—The Academy of Natural Sciences of Philadelphia has awarded its Hayden memorial geological medal to Professor T. C. Chamberlin, of the University of Chicago.—The Bruce Gold Medal of the Astronomical Society of the Pacific has been awarded to Professor Ernest W. Brown, of Yale University.

SIR AUCKLAND GEDDES, formerly professor of anatomy and principal-elect of McGill University, now a member of the British cabinet as president of the board of trade, has been named as British ambassador to the United States.

MR. J. OGDEN ARMOUR has made a further gift of six million dollars to the Armour Institute of Chicago. A new site for the school has been purchased at the cost of one million dollars, and five million dollars will be expended on buildings.—Yale University has received from Bayard Dominick, of the class of 1894, Yale College, gifts amounting to $40,000 for scientific exploration in the Southern Pacific Ocean. Professor Herbert E. Gregory, of Yale, is the active head of the expedition.

THE SCIENTIFIC MONTHLY

JUNE, 1920

RECENT CALIFORNIA EARTHQUAKES[1]

By Dr. ANDREW H. PALMER

U. S. WEATHER BUREAU

PRIOR to 1906, little scientific investigation had been made of earthquakes in the United States. The great California earthquake of April 18, 1906, focused attention upon the subject, however, and ever since that time seismology has made steady progress. Following the San Francisco catastrophe, the Governor of California appointed a commission to investigate the phenomenon which had caused unprecedented damage, so far as an earthquake in the United States was concerned. This commission consisted of eminent scientists, and their report was, and still is, the most comprehensive seismological treatise ever published in this country.

In order that the widespread interest in the study of earthquakes which followed the San Francisco disaster might be crystallized, and productive of research, an organization was formed called the "Seismological Society of America." This organization has grown slowly but steadily, and to-day includes in its membership about 400 of the leading seismologists of the world. It investigates individual earthquakes, encourages seismological research, and publishes a quarterly journal which is sent to about 500 addresses.

The number of seismographs in operation in the United States has grown rapidly during recent years. While there are a few privately owned instruments, most are maintained by the United States Government or by educational institutions. The following is believed to be a complete list of public seismographs in operation in North America at the present time:

[1] Published with the permission of the Honorable Secretary of Agriculture.

OUTLINE MAP,

Showing all Places in the United States and Canada where Seismographs were in Operation in 1919.

Maintained by the U. S. Coast and Geodetic Survey:
- Cheltenham, Maryland.
- Honolulu, Hawaii.
- Sitka, Alaska.
- Tucson, Arizona.
- Vieques, Porto Rico.

Maintained by the U. S. Weather Bureau:
- Chicago, Illinois.
- Northfield, Vermont.
- Washington, D. C.

Maintained by the Government of the Panama Canal Zone:
- Balboa Heights, Canal Zone.

Maintained by the Government of the Dominion of Canada:
- Ottawa, Ontario.
- Toronto, Ontario.
- Victoria, British Columbia.

Maintained by Educational Institutions:
- Berkeley, California; University of California.
- Cambridge, Massachusetts; Harvard University.
- Denver, Colorado; Sacred Heart College.
- Georgetown, District of Columbia; Georgetown University.
- Ithaca, N. Y; Cornell University.
- Lawrence, Kansas; University of Kansas.

Lick Observatory; Mount Hamilton, California; Univ. of California.
Mobile, Alabama; Spring Hill College.
New York, New York; Fordham University.
St. Louis, Missouri; St. Louis University.
San Diego, California; Raja Yoga Academy.
Santa Clara, California; University of Santa Clara.

Card used by Correspondents of the U. S. Weather Bureau in Reporting Earthquakes.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU (SEISMOLOGY).

Cross out words and parts not applicable, and fill in all remaining spaces. Use other side, if desired, for additional description and information.

Date of earthquake: ...., 19....

Time of beginning (use railroad time): Hour .... min., ..., a. m., p. m.

Location of observer:
- On mountain, hill, plain, in valley.
- Outdoors, indoors, 1st, 2d, 3d, ... floor.
- State ...., town ....
- Street ...., No. ......
- If in country, distance ...., direction ......
- from ....(nearest P. O. or town).

What doing: Lying down, sitting, standing, walking, ...

Onset of shocks: Abrupt, rapid, gradual.

Nature of shocks: Bumping, rocking, trembling, twisting..............

Intensity (give number, see scale on other side): ....

Number of shocks during earthquake: ....

Duration of each: ....

Direction of vibration: N.-S.; NE.-SW.; E.-W.; SE.-NW.

Sounds: No, yes. Before, with, after shocks. Faint, loud, rumbling, rattling.

Felt by: One, several, many.

Name of observer: ....

Address of observer: ....

(On back)

REMARKS.

EARTHQUAKE INTENSITIES. (Adapted Rossi-Forel.)

1. Felt only by an experienced observer, very faint.
2. Felt by a few persons at rest, faint.
3. Direction or duration appreciable, weak.
4. Felt by persons walking. Doors, etc., moved.
5. Felt by nearly everyone. Furniture moved.
6. Bells rung, pendulum clocks stopped. Alarm.
7. Fall of plaster, slight damage. Scare.
8. Fall of chimneys, walls cracked. Fright.
9. Some houses partly or wholly wrecked. Terror.
10. Buildings ruined, ground cracked. Panic.

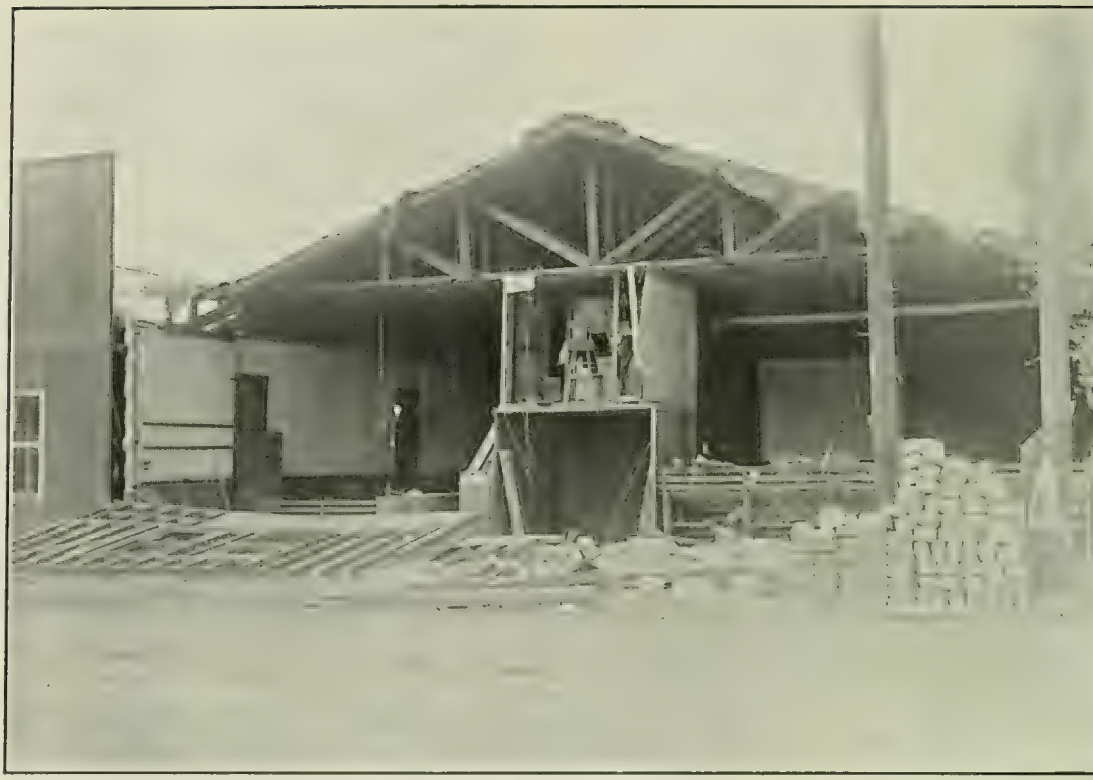


FIG. 1. A MOVING-PICTURE THEATER AT SAN JACINTO, CALIFORNIA, AFTER ITS FRONT WALL HAD FALLEN TO THE STREET DURING A RECENT EARTHQUAKE. The concrete-block type of construction is dangerous in a region of high seismicity. (Photograph by S. D. Townley.)

In accordance with a law enacted by Congress, the United States Weather Burean has collected and published reports of all earthquakes which have occurred in the United States since July 1, 1914. Besides the records obtained from its own seismographs, the Weather Bureau receives monthly reports of earthquakes recorded on the other instruments referred to above. Detailed reports are published in the *Monthly Weather Review*, an official publication. The seismological work of the Bureau is in charge of Professor William J. Humphreys.

Besides the work of collecting and publishing the reports of earthquakes automatically recorded, the Weather Bureau has inaugurated a novel work in collecting reports of all earthquakes strong enough to be felt by persons. Besides its regular weather stations, now numbering over 200, the Bureau has about 4,500 cooperative weather observers and special correspondents, most of whom are in the rural districts or in small towns and cities. Nearly all of these have volunteered to cooperate in the work of gathering earthquake statistics, a work which requires but a few minutes of the individual observer's time in the course of a whole year. The results in the aggregate are of great value, however. The system employed is very simple. Each observer is given a few cards, on each of which certain questions are printed. When an earthquake occurs in his vicinity, he is expected to answer the questions on the card, so far as that particular earthquake is concerned, and to forward the same immediately to a designated office of the Bureau. The system has been in successful operation for the past four years.

Count de Montesus de Ballore, who has perhaps done more than any other seismologist in the collection of earthquake statistics, has concluded that of the two classes of earthquakes, seismologic and seismographic, the former are the more worthy of consideration. Seismographs sometimes record earthquakes which are of artificial origin, or are due to the wind or the surf, and are therefore not earthquakes in the usual sense. Moreover, they frequently record vibrations from distant shocks which are not directly related to the seismicity of the region in which the instrument is located. It is thus apparent that seismographic records are apt to err in excess. Seismologic records, on the other hand, include sensible earthquakes only, these alone being the ones with which the public at large is concerned. Records of this nature are more likely to have an error due to deficiency, since light, though sensible, shocks occurring during the night may pass unobserved.

Few, if any, earthquakes of sensible intensity have passed unobserved in California during the past five years. This systematic and complete collection and publication of all earth-

FIG. 2. AN EXAMPLE OF THE DAMAGE SUSTAINED BY BRICK BUILDINGS IN AN EARTHQUAKE. The reinforced concrete building shown in the right background was comparatively unharmed. (Photograph by S. D. Townley.)

FIG. 3. A SAG-POND IN A SUNKEN AREA BETWEEN BAUTISTA CANYON AND THE SAN JACINTO RIVER, CALIFORNIA. All California earthquakes occur from the slipping and sliding of the earth's crust along fault planes, which are rifts or breaks in the rocks. Such a fault passes through this region, and the area is subject to frequent disturbances. (Photograph by Homer Hamlin.)

quakes strong enough to be felt by persons in California has resulted from the cordial cooperation of all those interested, principally through the following agencies: (1) The Weather Bureau has about 300 correspondents, well distributed throughout the state (see the accompanying figure), who report on cards all earthquakes felt. (2) The Seismological Society of America, whose headquarters are at Stanford University, receives many reports from its members, most of whom reside in California. (3) Mr. Homer Hamlin, a consulting engineer with headquarters in Los Angeles, has a large number of private correspondents in southern California who report to him all earthquakes observed.

The remainder of this discussion is based upon the reports of sensible earthquakes received through these various agencies during the four years, 1915–1918, inclusive. During this period California experienced 89 earthquakes per year, in the average. It is therefore readily apparent why California should be of unusual interest in seismology.

THE OCCURRENCE AND DISTRIBUTION OF EARTHQUAKES, 1915–1918

During the four years, 1915–1918, inclusive, California had a total of 357 earthquakes. With respect to the months of occurrence, these were as follows:

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1915......	8	5	7	13	9	8	8	3	4	10	4	4	83
1916......	4	5	2	1	6	4	6	12	8	6	6	6	66
1917......	3	4	7	7	12	29	18	9	6	7	5	2	109
1918......	2	3	11	24	11	13	12	8	4	3	5	3	99
Total....	17	17	27	45	38	54	44	32	22	26	20	15	357
Av......	4.2	4.2	6.8	11.2	9.5	13.5	11.0	8.0	5.5	6.5	5.0	3.8	89.2

It is readily apparent from the table that earthquakes are far more frequent in California during the summer dry season than during the winter wet season. The total number does not seem to vary greatly from year to year, the average being about 89 shocks. During every month of these four years, at least one earthquake was felt somewhere in the state.

It has long been recognized that earthquakes are more frequent at night than during the daytime, and the records of the past four years are no exception to the general rule. A study of 1405 California earthquakes which occurred from 1769 to 1915, inclusive, showed that on the average, there are two maximum and two minimum hours of occurrence. The extreme maximum occurs at 11 P.M., and the extreme minimum at 5 P.M. A secondary maximum occurs at 5 A.M., and a secondary minimum at 1 A.M. The double periodicity in the diurnal curve

FIG. 4. A VIEW OF A FLOUR MILL AT HEMET, CALIFORNIA, SHORTLY AFTER THE EARTHQUAKE OF APRIL 21, 1918. Brick and adobe buildings can not withstand severe earthquakes, whereas reinforced concrete and steel frame buildings will stand through the strongest shocks. (Photograph by S. D. Townley.)

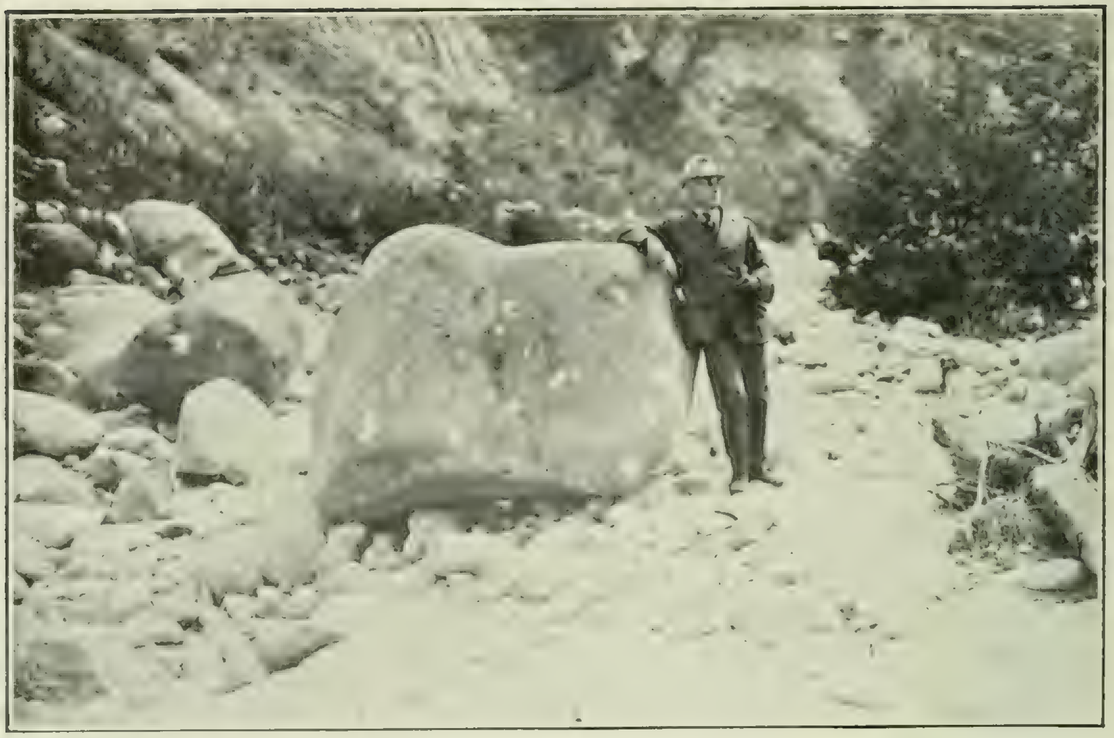


FIG. 5. AN EARTHQUAKE CAUSED THE BOULDER HERE SHOWN TO ROLL DOWN A MOUNTAIN SIDE IN CALIFORNIA. (Photograph by Homer Hamlin.)

reminds one of the diurnal curves of barometric pressure and of the tides of the ocean.

A region of high seismicity derives its instability from a number of causes, among which the following are the most important: (*a*) Folds in the earth's crust, either emerged or submerged; (*b*) marked variations of topography; (*c*) great ranges between ocean bottoms and adjacent mountain tops, as found where high mountains are close to a coast where the ocean bottom slopes precipitously to great depths; and (*d*) regions where secular elevation or depression is still in progress. All of these features are present in California, and collectively explain its high seismicity.

The real and ultimate cause of earthquakes is not understood. However, it is recognized that most earthquakes are related to movements of the earth's crust along vertical fault planes, which are simply breaks or rifts in the rock. These faults are numerous in California. The positions of those already recognized are shown in one of the accompanying figures. It is probable that in the course of time others will be discovered. There is a conspicuous parallelism in California, along NW.-SE. lines, of sea-coast, mountain chains, interior valleys, fault lines and earthquakes. Epicenters are found in a few places where the fault lines cross each other at right angles. Examples of these are the Monterey Bay region and the region of the Tehachapi Pass. Other epicenters occur where there are great contrasts of topographic relief within short distances. Examples of these are the Owens and Imperial Valleys. The frequent occurrence of earthquakes along an E.-W. line passing through the San Francisco Bay region suggests an action of bending, or faulting, or both, in the depths of the crust about an axis in this direction. This might be expected if the southern Sierra Nevada were rising faster than the northern. The fault-block origin and structure of the Sierra Nevada contribute largely to the frequency of earthquakes in California.

At one time it was believed that volcanoes and earthquakes were closely related, and that the latter were simply due to movements of submerged lava in volcanic regions. However, while this may be true in Italy and in Hawaii, most seismologists now agree that there is complete independence of seismicity from volcanism, as far as the United States is concerned. The Milne-Omori investigation of 8,300 Japanese earthquakes which occurred between 1885 and 1892 showed little relation between earth shocks and volcanoes. Only about three per cent. of Japanese earthquakes are of volcanic origin.

Because it has within its borders the only active volcano in

Fig. 6. A View of the First National Bank Building at Hemet, California, just after the Earthquake of April 21, 1918. (Photograph by S. D. Townley.)

Fig. 7. Business Houses in Southern California levelled to the Ground in a severe Earthquake, which caused a Property Loss estimated at $300,000. (Photograph by Homer Hamlin.)

the United States, California offered a unique opportunity during the past few years to test the relation between a volcano and earthquakes. Lassen Peak (altitude 10,437 feet, Lat. 40° 25′ N., Long. 121° 45′ W.) broke forth in violent eruption in May, 1914, and has been active sporadically ever since, with more than 250 observed eruptions. Whether or not there has been any relation between the eruptions of Lassen Peak and California earthquakes, has been a much-debated question. Though the Weather Bureau has numerous seismological observers within a comparatively short distance of the mountain, the number of earthquakes reported in that vicinity was not large, comparatively speaking. It might be inquired whether the presence of an active volcano would tend to increase or to decrease the number of earthquakes. Humboldt found a tradition among the natives of South America that so long as the volcanoes in their neighborhood were active, no danger from earthquakes need be feared, but if these remained quiescent for a long-continued period severe earthshocks might be anticipated. In a manner the volcano acted as a safety-valve, according to the tradition. So far as it has been possible to determine, not a single earthquake occurred in northern California simultaneously with an eruption of Lassen, several press dispatches to the contrary, notwithstanding. As a matter of fact, that part of the state farthest distant from Lassen Peak had the heaviest as well as the most numerous earthquakes.

It is probable that most, and perhaps all California earthquakes are due to slippings and slidings of the earth's crust for short distances along fault planes. The cause may be the strain imposed by some powerful force from without, or it may be simply the contraction of the earth itself. A tectonic rather than a volcanic origin is indicated by (*a*) the deep foci of the sensible shocks, (*b*) the long periods between the short preliminary tremors and the maximum vibrations, and (*c*) the vast areas over which the heavier shocks are felt.

California is not homogeneous in its seismicity, a fact which might be inferred from the distribution of faults, and from its topography. Earthquakes are frequent along the coast, and in the narrow Owens and Imperial Valleys. They are infrequent in the Sierra Nevada and Coast Ranges of Mountains, and they are rare in the Sacramento and San Joaquin Valleys. The San Andreas Rift, the longest and most conspicuous fault line in California, extends from Eureka, in extreme northwestern California, southeastward along the coast, through San Francisco, to detached southerly extensions in the Imperial Valley, and beyond the border of Mexico. The great earthquake of April 18, 1906, was due to a marked movement along this rift. As though the strain had been relieved by that movement, only a few shocks have since occurred along the northern portion of the fault. Eleven earthquakes occurred in San Francisco during the past four years. The Monterey Bay region showed marked seismicity, having had 23 shocks. The southern portion of this rift has been extremely active recently, and the Imperial Valley has been the most unstable region in the United States during the past four years. In fact, all of southern California south of the Tehachapi has shown marked seismicity, and the disturbances seem to be growing in frequency and in intensity. In the Imperial Valley a total of 70 earthquakes have been felt during the past four years, 26 having occurred in 1918 alone. In the city of Los Angeles, 30 earthquakes were felt in the four years, 17 of which occurred in 1917 alone. On the other hand, the Owens Valley, one of the recognized epicenters, has been comparatively quiescent. In this restricted region, where more than one thousand earthquakes occurred within a period of 48 hours on March 26–27, 1872, but 15 feeble shocks were felt during the past four years.

While the forecasting of earthquakes is as yet out of the question, certain principles are recognized. It is thought that when a great earthquake occurs, the strain in the earth's crust is relieved through movements along the fault plane, and that the region then remains stable for a time. The infrequency of

FIG. 8. A SCENE FIVE MILES SOUTHEAST OF VALLEVISTA, CALIFORNIA, SHOWING A LANDSLIDE CAUSED BY AN EARTHQUAKE. (Photograph by Homer Hamlin.)

shocks in San Francisco since the great disturbance of April 18, 1906, seems to verify this conclusion. On the other hand, some seismologists hold a theory that a great earthquake is preceded for months and years by an increasing number of light shocks. The violent shock centering at San Jacinto and Hemet which occurred April 21, 1918, was preceded by a large number of minor disturbances, while but few have occurred since that time. The growing number of earthquakes in the Imperial Valley would seem to indicate that a great disturbance may be expected to occur there in the near future. This region may therefore be watched with interest during the next year or two.

The Intensity of Earthquakes

The formula for seismicity involves the factors frequency and intensity. Of the two, the former carries the greater weight. It is generally recognized that the regions of most frequent earthquakes are also the regions having the severest shocks. Moreover, it is known that the intensity of an earthquake is directly proportional to the area shaken—in other words, the heavier the shocks, so much larger will be the area over which they will be felt.

An adapted Rossi-Forel scale of earthquake intensities is used by the Weather Bureau correspondents in reporting. In this scale of ten, the various intensities are described as follows:

I. Felt only by an experienced observer; very faint.
II. Felt by a few persons at rest; faint.
III. Direction or duration appreciable; weak.
IV. Felt by persons walking. Doors, etc., moved.
V. Felt by nearly everyone. Furniture moved.
VI. Bells rung; pendulum clocks stopped. Alarm.
VII. Fall of plaster; slight damage. Scare.
VIII. Fall of chimneys; walls cracked. Fright.
IX. Some houses partly or wholly wrecked. Terror.
X. Buildings ruined; ground cracked. Panic.

The late Professor Edward S. Holden, of the University of California, prepared the first catalogue of earthquakes on the Pacific coast, and the same was published by the Smithsonian Institution. From Professor Holden's study of the earthquakes of 129 years, 1769–1897, inclusive, he concluded that for any particular locality the number of really heavy shocks was quite small. The international reputation which certain cities bear as earthquake centers is, to a certain degree, unmerited. Thus at San Francisco there have been but three destructive shocks and four exceptionally heavy earthquakes in a hundred years, although there have been very many slight shocks and tremors. For the state at large, the most destruc-

FIG. 9. MASONIC HALL AT SAN JACINTO, CALIFORNIA, wrecked in the Earthquake of April 21, 1918. Note the piano under the roof at the left. Brick buildings can not withstand severe earthquakes. (Photograph by Homer Hamlin.)

tive earthquakes in modern times have been those of 1800, 1812, 1872 and 1906.

During the past four years, two earthquakes of destructive intensity have occurred in California. The Imperial Valley earthquake of June 22, 1915, was accompanied by the loss of five lives, and the destruction of property in California and in adjoining portions of Mexico. A severe shock felt throughout southern California on April 21, 1918, appeared to center at San Jacinto and Hemet. Because of its fortunate occurrence at a time when most people in that vicinity were absent from business districts, and many were out of doors (2:32 P.M., on a Sunday), no lives were lost, but great destruction of property resulted, the loss having been estimated at about $300,000. (See effects in the accompanying photographs.)

Of those earthquake reports of the past four years in which an estimate of intensity was made by the reporters, the great majority of shocks were of feeble intensity, just strong enough to show their occurrence by rattling windows, swinging doors, or by moving furniture. In only a few cases was actual damage done. In each of two years, 1916 and 1917, the total property damage resulting from earthquakes in California was under $1,000. About 80 per cent. of the earthquakes of the past four years were so light that they were felt at one station only, and not at two or more adjacent stations. Classified as to intensity, the California earthquakes of the past four years, so far as intensity estimates are available, are as follows:

	II	III	IV	V	VI	VII	VIII	IX	X
Number	111	197	172	128	27	9	16	8	2
Per cent	17	29	26	19	4	1	2	1	Less than 1

Number of Shocks in Each Earthquake

The typical earthquake consists of a series of preliminary tremors, one or more maximum vibrations, and a series of subsequent tremors. Reliable statements concerning the number of these maxima for any particular earthquake are, for psychological reasons, difficult to obtain. Concerning the attempts to secure such data in connection with the great earthquake of 1906, the California Earthquake Investigation Commission reported as follows:

> Many of these replies are rather questionable scientific evidence, inasmuch as many of them were in response to a leading and suggestive question, and very few of them have been subjected to the clarifying process of cross-examination.

While a seismograph would doubtless record many feeble vibrations in addition to the one or more strong enough to be

Fig. 10. A Fault Scarp in the San Jacinto Mountains about Two Miles East of San Jacinto, California, at Swoboda Springs. The fault plane here runs due east-west. (Photograph by Homer Hamlin.)

FIG. 11. A PHOTOGRAPH TAKEN IN THE BUSINESS DISTRICT OF SAN JACINTO, CALIFORNIA, FOLLOWING THE EARTHQUAKE OF APRIL 21, 1918. The center building was the telephone office. Note the difference in the damage sustained by the brick and the frame buildings here shown. (Photograph by S. D. Townley.)

felt by persons, the great majority of California earthquakes consist of but one sensible shock. An analysis of those reported during the past four years showed that 76 per cent. of them consisted of but one sensible shock; 17 per cent. of them consisted of two shocks; 5 per cent. of three shocks; 1 per cent. of four shocks; and less than one per cent. of five or more shocks.

DURATION OF EARTHQUAKES

The exact duration of the sensible earthquake can be determined accurately only by an acute observer equipped with a chronometer. While no such high degree of accuracy is here presumed, the testimony of the observers regarding duration is interesting, nevertheless.

Estimates ranged from a fraction of a second to more than a minute. It has been pointed out that the longer an earthquake lasts the greater will be its destructive effects. This is well borne out by the fact that the heaviest and most damaging earthquakes which have occurred in California during recent years were estimated to have lasted 60 seconds or more, in each case. On the other hand, most of the lighter shocks, those felt at one station only, were of but one to three seconds in duration. The former are general and ruinous, the latter are local and harmless.

Some of the observers felt incompetent to estimate the duration of an observed earthquake in seconds of time, and for this reason the record for duration of shocks is somewhat incomplete. However, a considerable number of estimates of duration were received. These have been classified as follows:

Seconds	1 or Less	2	3	4	5	6–10	11–20	21–30	31–40	Over 40
Number	77	56	39	27	53	67	44	29	8	30
Per cent	18	13	9	6	12	16	10	7	2	7

Sounds Accompanying Earthquakes

Ever since the time of Moses, descriptions of earthquakes refer to sounds accompanying these disturbances. The Scriptures are full of such allusions, and nearly every earthquake is said to have been accompanied by a great noise.

Psychological considerations play a prominent part in impressions of accompanying sounds. It is a well-recognized fact that people differ widely as to the range of audibility. Earthquakes which produce sounds observed by some persons may be apparently without sound to others. Personal equation, therefore, is important in this connection. Many persons are thrown into a peculiar kind of hysteria by experiencing an

Fig. 12. The Road between Hemet and Idylwild, California, blocked by Landslides in the Earthquake of April 21, 1918 (Photograph by Homer Hamlin.)

earthquake. Thunderstorms affect other people in the same manner. Generally speaking, the first earthquake one experiences does not produce hysteria. But if one passes through a disastrous earthquake, and suffers physical injury as a result of it, an earthquake subsequently experienced may easily cause hysteria through subconscious memory and association. When the observer is in such a disturbed state of mind, his impressions regarding sound are unreliable.

While it is possible that a few of the reporters were so influenced, the statements of accompanying sounds are not to be disregarded on that account. When sounds accompany earthquakes in California, they are usually of low pitch, that is, of relatively slow vibrations. The sounds may come from the ground or from the air, or from both. It was found that of the 357 earthquakes which occurred in California during the four years here considered, 34 per cent. were reported to have been accompanied by sounds. Of these, 65 per cent. were described to have been accompanied by rumbling, 17 per cent. by faint, indescribable sounds, 9 per cent. by loud sounds, 6 per cent. by rattling, 3 per cent. by roaring, and a few scattering reports included such expressions as explosive, tearing and shrieking. Some of these sounds occurred immediately before the earthquake, some were simultaneous with it, while some occurred immediately afterward.

General Considerations

Certain facts in connection with California earthquakes are of peculiar interest. For example, many and varied phenomena were caused by two widely-felt shocks which occurred at 6:44 and 6:55 P.M. on October 22, 1916. They were the strongest shocks felt in the state during the year, and they were observed throughout central and southern California. Of the 17 different stations from which reports were received, sounds were noted at but one, and in that instance the sound was described as faint. Waves 8 to 10 inches high rolled in on the west side of Buena Vista Lake for at least one hour after these shocks, and there was no wind blowing at the time. Near Maricopa, in the Kern County oil-fields southwest of Bakersfield, an oil-well that had been dormant for more than two years suddenly resumed its flow. The Edison Company's power line between Bakersfield and Los Angeles was broken. At San Bernardino the patients in the county hospital became so badly frightened that some time elapsed before they could be calmed.

A certain deep well located in the San Joaquin Valley temporarily became a geyser, and in the water ejected there were found a number of small fish without eyes, similar to fish which inhabit subterranean waters.

Temporary geysers are of frequent occurrence in a region of great seismicity. Preceding the San Diego earthquake of June 24, 1919, there was a marked disturbance of the Salton Sea, in Imperial Valley, a body of water formed twelve years ago when the Colorado River overflowed its banks and coursed into a part of the valley, most of which is below sea level. This disturbance, which occurred just before the earthquake felt at San Diego, 100 miles to the west, consisted of prolonged eruptions, for an hour or more, of a number of mud geysers, which tossed a mixture of mud and water, pearl gray in color, to a height of 60 feet. Geologists who have studied the valley have a theory that the geysers, which have erupted before, but never to such a height or for so long a time, serve as vents for gases formed far below the silt which forms the soil of the valley to an estimated depth of 1,800 feet.

Just south of the Mexican boundary line in the Imperial Valley there is a region comprising 30 to 40 acres where geysers are very active. This region is locally known as the "Volcanoes." On August 21, 1916, these geysers were in a state of great agitation. Mr. C. R. Rockwood, chief engineer of the Imperial Irrigation District, happened to be in the vicinity on that day. He described the disturbance as follows:

> The eruption occurred about 4 o'clock in the afternoon, and was the most violent I have ever observed during the many years I have been in this locality. The explosions lasted through a period of 11 minutes, during which time I presume there must have been 100 distinct explosions covering a lateral area 1,500 feet wide, each individual explosion being from 20 to 100 feet in width, throwing up columns of mud and steam to a height of 600 to 700 feet. Previous to this I have never witnessed one of these explosions that threw mud into the air to a height greater than 200 feet; while ordinarily the height is but 15 to 50 feet. The active explosions are in a submerged area, small in extent. This, however, is surrounded by a wider area of sulphur cones; while the hot sulphur springs extend for several miles both to the north and south of the more active center. There was no earthquake at the time.

In an investigation of gas rates conducted by the State Railroad Commission, a representative of one of the public service corporations operating extensively in northern California testified that earthquakes are a cause of leakage of gas from underground gas mains. As this loss is eventually borne by the consumer, it appears that the public interest would be served

FIG. 13. BUILDINGS IN THE BUSINESS DISTRICT OF SAN JACINTO, CALIFORNIA, WRECKED IN AN EARTHQUAKE ON APRIL 21, 1918. (Photograph by Homer Hamlin.)

by a study of the problem, with a view of preventing the loss, if possible.

Earthquake insurance is in growing demand. However, owing to the absence of trustworthy statistics in the past, rates have been more or less arbitrary, and most of them have had no scientific basis. In a few years, however, it is hoped that more reliable data will be available on which to compute rates.

California has numerous astronomical observatories. It has occasionally happened that astronomers have detected earthquakes while observing a star through a telescope. Mr. Wendell P. Hoge, of the staff of the Solar Observatory of the Carnegie Institution of Washington located on the summit of Mount Wilson, California, noticed such an earthquake on March 22, 1916, while watching a star image in a 60-inch telescope. He reported:

> Oscillations of the star image in the field rapid and short at first, becoming more marked in the middle, and diminishing at the end of the disturbance. Evidently a very faint shock.

The most widely felt earthquake in 1917 occurred at 10:07 P.M. on May 27. In the Imperial Valley some damage resulted through the cracking of walls, people were much frightened, and at a school in Brawley where commencement exercises were in progress several women and children fainted as a result of hysteria. Concerning this earthquake Mr. Hoge, of the Solar Observatory, reported:

> This earthquake was observed by Astronomer Dr. Harlow Shapley while observing with the 60-inch telescope. Star image oscillated rapidly back and forth in field of view in eyepiece. Two shocks close together were observed.

Various Japanese investigators have found that the barometric gradient offers a means of discovering unknown seismic zones or faults, as it was shown that the prevailing gradient at the time of an earthquake was nearly perpendicular to the fault. The method was found more feasible and more accurate than that of constructing the zones statistically by locating a large number of epicenters. In California, with well-developed barometric gradients occurring during the winter half-year, and with frequent earthquakes occurring throughout the year, this method offers an opportunity for some student of seismology to do useful work in locating fault zones which are still unrecognized.

San Francisco has learned its lesson in the matter of fire protection in a region of high seismicity. When that city was destroyed by fire in April, 1906, it was because the water mains had been broken by the earthquake, and there was no water available for fire-fighting purposes. The water system has

FIG. 14. STORE BUILDINGS IN THE HEART OF SAN JACINTO, CALIFORNIA, WRECKED BY AN EARTHQUAKE ON APRIL 21, 1918. Because of the fortunate time of occurrence, at 2:32 o'clock on a Sunday afternoon, the business district was largely deserted, and no lives were lost. (Photograph by Homer Hamlin.)

Fig. 15. A Building on Main Street, San Jacinto, California, wrecked in an Earthquake on April 21, 1918. (Photograph by Homer Hamlin.)

been reconstructed in such a way that an earthquake could not destroy its efficiency. But in the matter of building construction, much is still to be learned. Steel-frame and reinforced concrete buildings will stand through a severe earthquake. Wooden buildings, too, will remain unharmed in destructive shocks, since they will yield to strains. Brick and concrete-block buildings are easily destroyed. But the most dangerous type of the construction is the primitive adobe, which is still in use among Mexicans and Indians. The lives lost in the Imperial Valley earthquake of June 22, 1915, resulted from the collapse of adobe buildings. In San Francisco the owners of certain steel-frame apartment buildings advertise their property as being "earthquake-proof." During the Exposition year, 1915, many visitors in San Francisco were disappointed in but one respect. They spent a week or two in that city without experiencing a single earthquake, whereas they came expecting to feel one at least every day. In the course of time laws will doubtless prevent the construction of projecting cornices in buildings, and the erection of overhead signs and electric wires in cities like Los Angeles and San Francisco, where a recurrence of severe earthquakes may be expected from time to time.

At 3:01 A.M. on July 6, 1917, an earthquake occurred in the Owens Valley which caused a break 160 feet long in the concrete flume of the Los Angeles aqueduct. Under the direction of Mr. William Mulholland, chief engineer of the aqueduct, the damage was temporarily repaired by bridging the break with steel pipe. Since that time the flume has been rebuilt and reinforced. The water supply in Los Angeles was not cut off, because the break occurred above the Haiwee reservoir, which has a capacity sufficient for the storage of several weeks' supply of water for the city. The city of San Francisco is now constructing a similar aqueduct which will eventually be 200 miles in length, bringing water to the city from the Hetch Hetchy Valley. As a result of the damage sustained by the Los Angeles aqueduct in this and in other earthquakes, reinforced and specially adapted construction is planned for the San Francisco waterway in those places where it will cross recognized fault planes.

The term "earthquake weather" is often encountered in California. Those who use the term are unanimous in referring to a condition of hot and calm weather, without much cloud, but usually with more or less haze and diminished visibility. The condition referred to is similar to that which precedes a summer afternoon thunderstorm in the Middle West. While many of the earthquake observers believe that there is an intimate relation between earthquakes and the weather, meteor-

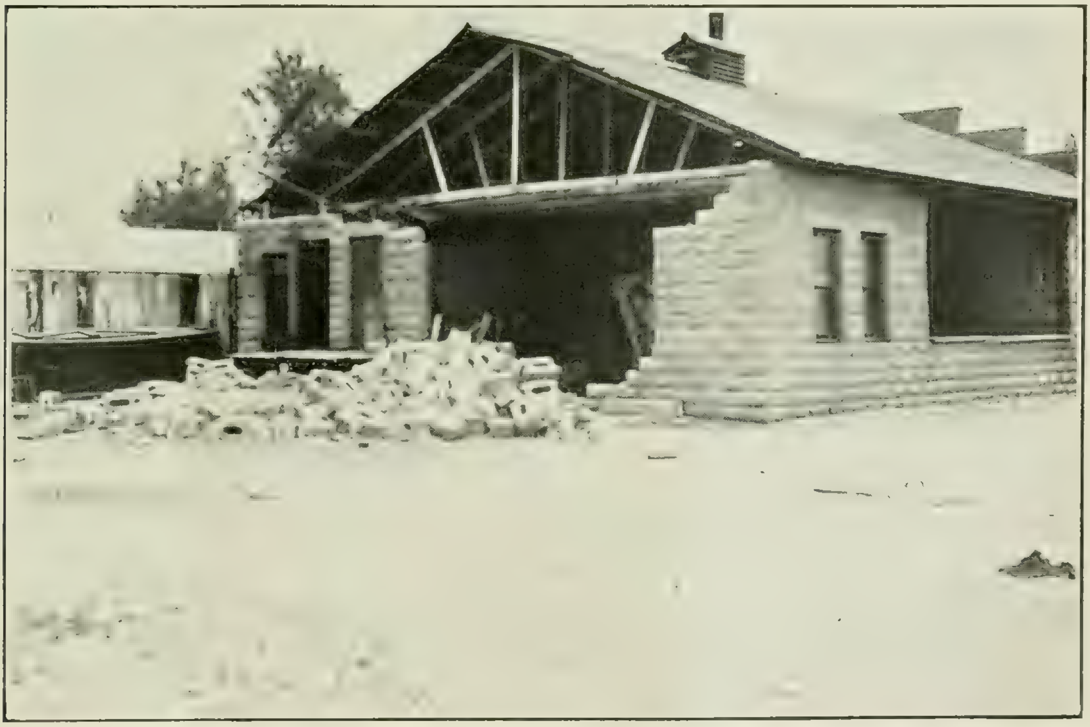


Fig. 16. A Concrete-block Building wrecked by an Earthquake. Experience has shown that reinforced concrete, steel-frame and wooden buildings will stand through severe earthquakes, whereas brick, concrete-block and adobe buildings are easily destroyed. (Photograph by Homer Hamlin.)

ologists firmly maintain that there is no real relation. Professor W. J. Humphreys, of the Weather Bureau, believes that the apparent relation can be explained in terms of human psychology,—that the observer under the weather conditions described above is in a sensitive and expectant mood, with a feeling of apprehension, and hence feels slight earthquakes which under other conditions might pass unnoticed.

The attitude of the California newspaper editors toward the reporting and the publishing of earthquake data is curious. There seems to be a gentlemen's agreement among editors to omit all reference to the occurrence of earthquakes. Frosts, fleas and earthquakes are tabooed subjects. Such information does not attract settlers, nor does it aid in selling real estate. Perhaps it is for these reasons that seismologists receive neither sympathy nor support from the press. The general public promptly plunges into a kind of hysteria when a severe earthquake occurs, but soon relapses into complacent indifference when the immediate danger is over. Seismological research is therefore left largely to a few individuals like Dr. J. C. Branner, of Stanford University, the real founder of the Seismological Society of America, and who remains to-day the most enthusiastic student of seismic phenomena in America.

A discussion of California earthquakes would be incomplete if it did not attempt to correct certain false notions concerning the danger from earthquakes. While the seismicity of the state is acknowledged to be high, the highest in the United States, the actual danger to one living in any particular locality is small indeed. Though written almost 50 years ago, the following words of General Hardenburg, U. S. Surveyor-General in 1871, are still true:

> Reasoning from the foregoing historical facts, I am firmly of the opinion that the earthquakes of California are not so much to be dreaded as is generally supposed; in fact, that they are far less dangerous to life and property than are the hurricanes of the South, or the summer tornadoes of the North.

A POLICY FOR THE U. S. NATIONAL MUSEUM

By Professor T. D. A. COCKERELL

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IT is related that a couple of habitual and impecunious pedestrians, sitting by the roadside, engaged in conversation as follows:

"I wish I had a million dollars."

"Suppose you had, would you give me a thousand?"

"No."

"Would you give me a hundred?"

"No."

"Well, wouldn't you even give me a dollar?"

"No, I wouldn't give a cent to a man too —— —— lazy to wish for himself!"

Perhaps this story may throw light on the failure of the scientific public to get perfectly satisfactory service from the National Museum. We have been too lazy, or too indifferent to wish for ourselves. We have expected some one else, vaguely "the administration," or Congress, to do the wishing, and as a result hand out to us our share of the proceeds. We have rather forgotten that we live in a democracy, and that the will to do must be ours if we are to be properly served. If recent events have suggested that another theory obtains in influential quarters, it is the more necessary for us to be intelligently articulate. It is indeed true that the National Museum represents a highly technical branch of the public service. As such, it must not be subject to the light winds of public fashion or fancy, and still less to political dictation. It must have an essential stability, a continuity of plan and purpose through the centuries. It must be administered by experts, who must be trusted and given the necessary powers. Granting all this, it must still remain true that the purpose of the institution is service, and that public support should depend on public approval. It is surely the duty of the scientific fraternity to state the functions and express the needs of the museum. Demands backed by united scientific opinion should have weight with the public, and hence eventually with Congress. In approaching the practical problems of such an institution as the National Museum, it is readily seen that these divide themselves roughly into two groups. First, there are those matters which have to do with internal administration, or which primarily involve rules and customs rather than the expenditure of money. We find, for example, that the correspondence of the curators is (or recently was) involved in a system of red tape which is extremely vexatious and has little relation to practical utility. Along with this we have found a lack of adequate supervision in certain quarters, permitting practises detrimental to the collections. There is no large institution, I presume, which is wholly free from administrative defects. This condition arises out of the very nature of things, and can only be controlled by perpetual vigilance. If the institution is governed under a system of cast-iron rules, regulating every detail of procedure, it is incapable of changing with the times and meeting with new requirements. If, on the other hand, it is made as free as is consistent with order, and every latitude is allowed to individuals, it will never happen that all will prove ideally wise, faithful and industrious. The first of these alternatives is intolerable in America, but the second involves greater responsibilities for all concerned. As regards these matters of internal administration, it must be said to-day that noteworthy progress has been made. From the days of the foundation of the Smithsonian Institution the curators have rendered ever increasing aid to scientific men all over the country, and have enormously added to our knowledge of American and even Old World natural history. There is probably hardly a zoologist, botanist, geologist or ethnologist in the country who can not recall being assisted, not once, but many times. This assistance has very often come when it was most needed—when the man was young and unknown, striving to get his first hold on some branch of science. The magnitude and importance of these services can hardly be exaggerated; they have not been appreciated by the public because no combined or clear presentation of them has ever been made. The official reports, while giving many exact details, are too dry and too little humanized to attract general attention.

In the department of entomology, with which I have been especially concerned, a concerted effort is now being made to put things on a better footing, and develop collections in all respects worthy of such a nation as ours. There are many practical reasons for this. Enormous losses to crops and health have resulted from the attacks of insects. Insects have afforded the material for the elucidation of some of the most important and far-reaching biological problems. Insects also afford ideal material for amateur study, as they are present in abundance everywhere, and their investigation requires little space or expenditure of money. So whether we are concerned with the production of food, or the public health, or the philosophy of nature, or the development of some of the finer qualities of the human mind, we turn to the abundant life of the insect world. The Entomological Society of America and the Association of Economic Entomologists have for some years had committees working on the museum's entomological problems. In their efforts they have had the cooperation of the museum curators and officials, and to-day there is general agreement concerning the policy to be pursued, as well as renewed interest in the whole matter. Whatever can be done under existing conditions will be done—is being done.

At this point, however, we come to the second great group of problems—those which involve the expenditure of money and hence greater public support. It is useless to criticize officials for not making bricks without straw. They may perhaps be criticized for not putting up a better fight; but those who are not on the inside have little idea of the continuous and persistent struggle which has resulted in the gains so far obtained. Here again we seem to forget that we are a democracy, that Congress is responsible to the people rather than to the officials. Members of Congress usually know next to nothing of science, and have no means of estimating the validity of the claims made upon the national purse. They know that museum officials are pushing their own interests, and are likely to discount their statements accordingly. They also fail to perceive any political advantage in helping the museum, since their constituents appear to be absolutely indifferent to the matter. It is surely for us, who are scattered over the country, to make ourselves heard, and create a demand to which Congress will eventually respond. It is for us to make up our minds what we want and tell the people—in short, to carry on a propaganda. Progress, in such a country as ours, involves publicity.

Going into details, it would be easy to write a book on the policies and functions of the museum. It is, however, possible to state the more salient ones in a few words. In the case of entomology, for example, the prime needs, following a policy of necessary expansion, are curators and space. The latter involves a separate building, since the existing one is already overcrowded. The curators should be sufficient to take care of all the collections and carry on continuous researches. We are now starting a movement to greatly increase the collections, which are very inadequate in certain directions. It is expected that great quantities of material will be donated, as entomologists perceive that the specimens are being taken care of and studied. Thus the museum will, through making provision as indicated, reap large rewards without further expense. It is in this manner that the British Museum has built up its magnificent series of the insects of the world.

These proposed developments are entirely in line with past progress. Others involve more novel methods or activities. Expeditions such as those headed by Mr. Roosevelt have greatly enriched the museum and added to knowledge. But we now need a systematic policy of exploration, especially in the Western Hemisphere. The great Biologia Centrali-Americana was financed and published by Englishmen. In earlier days, the Germans elucidated the fauna and flora of Brazil. It should be a pan-American policy to investigate every part of the Western Hemisphere, and describe its products. In this work, so far as the natural sciences are concerned, the United States National Museum should take the lead, seeking the cooperation of every nation concerned. The duty and advantage of such a policy are so obvious that they hardly require discussion. Here, at least, is a field for the cultivation of friendly relationships and civilized intercourse, and an opportunity for the increase of useful knowledge. Steps have already been taken in this direction; important and successful expeditions have gone out from Harvard, Princeton, Yale, Cornell, Michigan, Iowa, Indiana, the New York Botanical Garden, the Carnegie Museum, the American Museum of Natural History, not to speak of the work of the National Museum itself. The results are already great, and interest in many quarters is keen. It only remains to develop a concerted plan, and seriously set about it to cover the entire field. We must do somewhat as the astronomers did, when they undertook to map the sky and enumerate the stars. Our undertaking is of even greater magnitude.

A quite different need, but growing out of those already mentioned, is a National Museum printing establishment. The American Museum in New York does its own printing, and finds the policy advantageous in every way. Under the present law, the National Museum is obliged to print its Proceedings at the Government Printing Office, which is already more than crowded with work. The result is great delay, and great difficulty in getting the work done. At the present moment conditions seem worse than ever before. If the museum had its own establishment, with sufficient funds to carry it on, it might publish all the research work done under its auspices or on its collections without difficulty and without delay. The printers would acquire great skill in the special kind of work required, so that typographical errors would be reduced to a minimum.

As things are now, even if we had all the facilities referred to above—plenty of curators, adequate collections and room, the whole organization would be stultified by the impossibility of getting more than a small fraction of its results before the public. Furthermore, many would be discouraged from writing on museum materials, as indeed they are to-day. There is little advantage in accumulating knowledge if it can not be communicated to those concerned. There is still another major policy which should be defined. The National Museum should become national in a larger sense. It seems to me that it should establish branch museums, in cooperation with local authorities, in a number of different states. Possibly half a dozen such branches might be created in the near future. In them could be kept special collections illustrating the natural history of the regions they represented. They could also receive materials on loan from the central museum, thus making them accessible to many who could not visit Washington. The abundant duplicates at present in the National Museum could be distributed to them. The various expert curators could spend some months in them, working on the local collections and arousing local enthusiasm. In this way every section of the country would come to know something of the activities of the National Museum, and would value its services. The increased expense would be more than met by increased popular support. I understand that the museum authorities have for some time had a plan of this kind in mind, but I do not know any details.

It is quite conceivable that the underlying principle of the branch museums might even be extended to cover the whole of North and South America. The museums outside of our boundaries would then be affiliated or cooperating museums. But in essential function there might be little difference, except that the benefits in the way of loans would be more completely reciprocal. Such a pan-American museum policy could only have good results. Underlying all these reforms and developments should be the policy—I believe not clearly enunciated in the existing law—of making the museum primarily a research organization. Its function should not be static—that of simply caring for the collections—but intensely dynamic. It should and must be one of the greater influences for human advancement and human welfare. By making it a greater source of knowledge we shall at the same time make it a great educational institution, teaching educated people and experts from the Atlantic to the Pacific, and indirectly fertilizing every field of educational activity. Could there be a grander function, or one more worthy of public support?

Gustaf Retzius

GUSTAF RETZIUS, 1842–1919

By Dr. OLOF LARSELL
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IT is given to few men to become outstanding leaders in any field of science, and positions of eminence simultaneously in several fields are at the present time almost impossible of attainment. Such a position was, however, occupied by the subject of our sketch in each of the sciences of anatomy and its sister, anthropology. To both of these fields of knowledge he made contributions of enduring worth in some of their most difficult branches. As if this were not sufficient to absorb his energy and zeal, several volumes of poems, both original and translated, numerous sketches of his extensive travels in other lands, political writings, and other forms of literary endeavor emanated from his prolific and resourceful pen.

Magnus Gustaf Retzius was born in Stockholm, October 17, 1842. He came of a family which was distinguished in science and medicine, not only in his native land, but at least in the case of his father, throughout Europe and America.

His father, the celebrated anatomist and ethnologist, Anders Adolf Retzius, was professor of anatomy at the Caroline Medico-Chirurgical Institute of Stockholm. This position he held from 1824 until his death, which occurred in 1860. Anders Adolf Retzius was born in Lund on October 13, 1796. He studied at the University of Lund, and then for a time at Copenhagen. On his return to Sweden he gravitated toward the capital while still a youth, for we learn that in 1818, Anders Johan Retzius, the father of Anders Adolf, who had been ill for some time, received a stroke which paralyzed the lower part of his body. Anders Retzius the younger, therefore, came to Lund and took his father to Stockholm.

On December 27, 1823, Anders Retzius, the father of Gustaf, was appointed professor of veterinary science in the veterinary school of Stockholm and, on September 16 of the following year, he was made profesor of anatomy at the Caroline Medico-Chirurgical Institute. He was then 28 years of age. This position he continued to hold until his death, as previously stated.

The Caroline Institute had been founded but a few years previously, in 1815, and it appears due very largely to the organizing ability and the scientific work of Anders Retzius that this medical school attained the position of prominence which it has come to occupy in the Scandinavian countries.

Anders Johan Retzius, the grandfather of Gustaf, was professor of natural history at the University of Lund from 1787 until 1812. He appears to have been interested particularly in rocks and minerals, for he presented a collection of these to the University in 1815, which is mentioned in the record of the University celebration in 1897, which marked the quarter century of the reign of King Oscar II.

An uncle of Gustaf, Magnus Christian Retzius, from whom the subject of our sketch apparently received his first name, which, however, was seldom used in later life, was also born in Lund. He was two years the senior of Anders Adolf. He completed the medical course at Lund and received the degree of Doctor of Medicine in 1815. Soon after this, apparently, he removed to Stockholm. Before taking his degree he had served as battalion surgeon with the Swedish army in the campaign against Norway in 1814. In later life he occupied various positions of eminence on the medical staff of the army and also built up an extensive medical practice in Stockholm.

The scholarly traditions of his family showed themselves by numerous medical and anatomical contributions. Magnus Christian Retzius died October 1, 1871.

By the removal of the two brothers to Stockholm, and by the bringing to that city also of their father in his old age, the Retzius family was now established in the capital city of the country. Here Anders Adolf married Emilia Wahlberg, also of a family distinguished for its love of natural history and scientific pursuits. One brother of the mother of Gustaf was a botanist, apparently of some note in his own country, and another brother was an engineer and explorer.

With this background it is not surprising that the young Gustaf should have developed the remarkable zeal for biological science which characterized his work for more than half a century.

Concerning his boyhood and his veneration of his father we have a glimpse in a letter[2] which he wrote in 1892 when he was at the height of his powers, and already famous. This letter was written to the editor of a series of short sketches and auto-

[2] Retzius, Gustaf, " Självbiografisk skizz. Autografin och porträter af framstände personer," Ser. 3, 1892, Hft. 9 b.

graphs of the leading men of Sweden. Because of the illumination it sheds on the character of the son himself it is worth quoting in full in a translation which has attempted to preserve the spirit of the original, although the phraseology on that account appears here and there somewhat clumsy in the English.

Mr. Editor:—

When to-day, April 18th, the anniversary of my father's death, I received your letter requesting me to send you my autograph, it appeared particularly fitting to sketch a few of the pictures from the past which such an anniversary calls forth for recollection.

It is now 32 years since my father, after a few days' illness, was suddenly sent away from his comprehensive and influential work. He had recently been greatly pleased that the same Spring I should become a student and that soon thereafter he should have me as a disciple in the anatomical lecture room in which for more than thirty-five years with never-tiring energy, love and wisdom he had fostered generation after generation of the healing art's young followers. And I was delighted at the prospect with all the enthusiasm of youth. His death put an end to the hopes of us both, and although a couple of weeks later I donned the white cap in Upsala—after having with my father's approbation "hopped over" the fourth ring in the gymnasium—yet I felt to the full extent the irretrievable loss I had suffered.

I had by the exertion of all of my young strength worked myself through the long hated requirements of the school, with its narrow-minded coercion, unnecessary grinding, needless and musty lore, in order to be initiated into the world where all of my desire was: nature's wonderful world, under an awake, inspired and learned father's leading.

And thus the leader went away, just as I stood at the threshold. I felt myself uncertain, groping. But I cast myself in, however, with other seekers after knowledge, and so proceeded further on the way, sometimes with tottering steps. But the way led nevertheless forward.

When I now in retrospect think upon how it came about that I followed in my father's footsteps, that I not only became a naturalist, but particularly anatomist, histologist and anthropologist, then I see that it occurred because he, although gone, has yet been my invisible leader. The seed which he implanted in my mind in my years of childhood have long afterward sprouted.

In very truth during my youth neither my father nor I had time for much talk with one another. He was occupied all day in absorbing work, with his instructing, his scientific researches, his correspondence and with a thousand other tasks which were foremost for his restless spirit's industry. I also had my constant school-going which not seldom led to real over-exertion. But I met him at meal times, saw and heard him often in company with others, especially noted naturalists, Swedish as well as foreigners, the last named of whom sought him in Stockholm on their summer trips. I was permitted during my gymnasium years to accompany him on journeys to Germany, France and Switzerland and was thus, in his company, guest of the contemporary most outstanding men among naturalists, such as Johannes Müller, Ernst Heinrich Weber, Rudolph Wagner, Bischoff, Justus Liebig and many others. I heard them discuss scientific problems with a zeal, a geniality, a devotion, which must make an impression on the mind of a youth. I obtained also thus a little insight into what scientific work is and what it requires. I received a glimpse that it is not on the king's highway one pursues his calling, that the cross-beam demands on all sacrificing patience, a perseverance without limits, an unheard-of spirit of sacrifice. I understood, therefore, even then, better my father's industry at home, his giving himself up to science, his " holy fire."

But there was also something else which made an impression on my young mind. My father worked not alone with books and desk. " Search first and read afterward " was one of his principles. He opened always first nature's book before he turned to the book-shelf. He seized upon knotty problems (certain knots) knowingly, with lively interest, strove for progress in all directions, but foremost of all it was Biology which urged him on, not alone human anatomy and physiology, but all of living nature. Therefore he always tried to plant in his little garden new and useful plants. On this account he sent to his home strange living animals. I long had my trundle-bed in the same room where these animals were generally kept, my father's work- and writing room in his dwelling-house at the Caroline Institute, of which institution he was the inspector and leader, indeed the creator. I remember even yet so well how a large human skeleton stood beside my bed, and how in the window were placed aquaria and jars with lizards and tree-frogs, indeed one of the bellowing giant-frogs of Brazil which when it got loose made room-high jumps. There were casks with young salmon-fry, whose further development my father studied. And each spring when the ice broke up, he took me with him to Kungsholmbrun, where we clattered down on the stone piers to the water's edge and gathered small water animals, infusoria, bryozoans, and worms, which we took home to the aquaria. I shall never forget my father's enthusiasm when he observed under the microscope the wonderful life which was unfolded in the water of these aquaria, and of which he with his spirited descriptive art tried to give me an inkling. I shall never forget his burning interest, his love of truth and the alert, keen look, concerning which a foreigner one time said that in case there was any proof needed for immortality, Anders Retzius' glance was such a proof.

Only a single time was I permitted to hear my father lecture in his auditorium. He took me, naming I know not what reason, with him to the anatomical lecture-room and allowed me, gymnasium student, to sit on a bench in the midst of the large crowd of medicophiles, to whom I looked up with reverence. The lecture to which I then listened stands out to-day, after 34 years, in my memory as if I attended it yesterday. Such an original presentation have I never seen or heard since.

He lectured on the trachea, its structure and function. With a vivacity, which for a man of 60 years must be thought phenomenal, with a youthful verve and enthusiasm, of which very few teachers even in their prime are in possession, he gave an illustrated picture of this organ's wonderfully simple, and yet so ingenious structure, and its great importance for mankind. He entered with all his might into his subject. His mobile features made clear the shades of meaning with a clever mimicry. His hearers followed with intense attention the by no means arranged, but all through, spirited exposition. One immediately caught the contagion of zeal and laughed heartily at the original fancies which spiced the lesson, which had quite a different form than that of the ordinary dry lecture. I have often reflected since then over it and seen that in such manner lectures may have much greater influence than as ordinarily given.

I have here in a few rough sketches tried to delineate the impulses which my father, notwithstanding his death, gave me during my years of youth for my journey through life. Much might be said here of the great example which his outstanding personality gave to all who came into contact with him. Much might also be said of the influence which my mother with her unceasing, devoted interest, and which her brothers, the botanist P. F. Wahlberg, and the engineer-naturalist J. A. Wahlberg, had on my orientation—not least the last named, who daily took his meals at my parents' home. He, who dreamed of nature, often took me as a child, with him on his rambles in the suburbs of Stockholm. He taught me to speak the flowers' "language," and the birds' song—the only music I even to-day understand. And it was earnestly debated that I, as a ten-year-old boy, should go with him to the unknown lands of inner Africa, on his last expedition, where he laid down his life. But if a description of this man's noble personality might be of interest here, yet has this autograph already grown beyond its prescribed limits and it is time to conclude.

The scattered pictures and impressions which I have drawn from my youth may serve at least to show "why I became a naturalist."

But they may serve at the same time to show something which may be of general interest. They may give to those who have the upbringing of children on their hands, a glimpse of the important weight of the influences which in the home and in the environment, affect the child's future development. It is not so much the lessons of the school, admonitions and punishments, which up-foster and give foundations. It is in a much greater degree *living examples.*

Gustaf Retzius

Stockholm, 18 April, 1892

Concerning his studies at Upsala there is little or no information at present available. Since he entered in 1860, at the age of eighteen, and did not receive his medical degree until 1871, he must have spent a number of years at Upsala. He then attended medical lectures at the Caroline Institute for some time. It appears likely that his medical degree was received from the University of Lund, as one of his biographers states, instead of from the Caroline Institute as several others imply, since it was not until 1874 that the Caroline Institute attained the right held by the state universities of Lund and Upsala, to hold examinations and confer degrees in its special faculty. Many students from all the Scandinavian institutions took their examinations and degrees at Lund, after pursuing their studies at one or another of the other schools.

In these years of his university life, Retzius already began the productive literary and scientific labors which were soon to bring him distinction. In 1864, at the early age of twenty-two years, he collected, edited and published his father's contributions to ethnology, together with some of his father's letters. About this time also he began the comprehensive researches which resulted thirty-six years later in his monumental work, "Crania Suecica Antiqua," published in 1900. In 1871, the year in which he received his medical degree, he published a 58-page volume of sonettes, which must have been the accumulation of a number of years, and the following year, 1872, he published a small volume of translations into Swedish of some of the poems of Robert Burns.

This purely literary work, however, was to lapse for a number of years, for in 1871 he became a docent in anatomy at the Caroline Institute. He had already, in 1869, begun a series of researches in collaboration with Axel Key on the anatomy of the nervous system and the connective tissues which gained recognition from the French Academy in the bestowal upon Retzius of the Monthyon prize. In 1873, in company with Lovén and Nordensson he undertook a journey to Finland and Russia for the purpose of studying the anthropology of the Finns. This resulted in the publication in 1878 of his important work on "Finska Kranier." A monograph on "Das Gehörorgan des Knockenfische" appeared in 1874, and was the forerunner of important researches on the auditory organ of vertebrates, the larger results of which were published in 1881 and 1884, comprising two volumes with the title "Das Gehörorgan der Wirbelthiere." The figures of Retzius representing the inner ear and the organ of Corti are still reproduced in many modern text-books. These researches on the auditory organ were continued many years later after the introduction of the newer methods of nerve staining, and form the basis of several contributions in his "Biologisches Untersuchungen." They reveal his abiding interest in this difficult subject.

In 1877 Retzius was made "personligt" professor of histology at the Caroline Institute, and in 1888 was advanced to a full professorship. This, however, he resigned the following year in order to devote all his time to his investigations, an apparent ambition to occupy the position so long held by his father having been satisfied.

During the eleven years of his assistant professorship numerous contributions were made to histology and neurology. In 1881 and 1882 appeared two volumes of researches by himself and younger workers under his direction on purely histological subjects. These two volumes constitute the first series of his "Biologisches Untersuchungen." Because of other duties as he states in the preface to Volume I. of the new series which was begun in 1890, and because he found opportunity to publish a series of researches in the proceedings of the Biological Society, the "Biologisches Untersuchungen" was allowed to lapse as a distinct publication for a number of years.

Some of these other duties to which he refers were of a nature usually quite foreign to the laboratory man. From 1884 to 1887 he was chief editor of the *Stockholm Aftonbladet*, a daily newspaper of considerable circulation. Retzius became connected with the *Aftonbladet* through his marriage with Anna Elizabeth Hierta, the daughter of the owner and founder on the paper, Lars Hierta. Hierta was a man of considerable wealth and of influence in his country. He held various offices, including a seat in the riksdag at various times. After his death, which occurred in 1871, his widow gave 100,000 kronor to the "hogskola" of Stockholm to establish a chair of political economy, and several years later she established a foundation of 400,000 kronor in memory of her husband.

It was this marriage, sympathetic as well as fortunate financially, which placed ample means at the disposal of Retzius for his later scientific work, and for the publication of this in the sumptuous form in which most of it is found.

A year after the resignation of Retzius from the chair of anatomy at the Caroline Institute, that is in 1890, appeared Volume I. of the New Series of "Biologisches Untersuchungen." These volumes appeared at intervals of from one to three years, until by 1914, eighteen volumes had been published. They are of folio size, illustrated with handsome plates, some 478 in all, many of which are in colors. The text is usually brief, but carefully descriptive of the various subjects treated, and in addition to the description, contains a review of the literature.

These volumes contain only work which he himself had done, as he states in the preface to the first volume. By far the greater number of the thousands of figures included in the numerous plates are indicated as drawn by his own hand. He employed an artist for such figures as required delicate lines and shading, but with a few and unimportant exceptions, the figures which were drawn from microscopic preparations, were his own work.

Retzius was very generous in his acknowledgment of the help afforded him by artists and photographers when he employed them. In the last three volumes of the "Untersuchungen," which include much cytological work, he also expresses great appreciation of the services of his technician for the beautiful preparations on which these studies were based.

It is impossible in a brief space to present any adequate conception of the content of these eighteen volumes. The first nine volumes were devoted very largely to the nervous system of various invertebrate groups, as the crustaceans, the annelids and others, and to the histology of different types of nerve terminations in both invertebrates and vertebrates. To these investigations he applied the then new Golgi and methylene-blue methods of staining. Many of these descriptions and figures have become an integral part of every general treatise on the histology of the nervous system.

Beginning with Volume VIII., however, appeared also a series of studies on the brains of eminent men. The first of these was a study of the brain of the astronomer, Hugo Gyldéns. In the preface to this volume, Retzius in a manner apologizes for the fact that three years had elapsed since the appearance of the last volume, but states in extenuation that "my time has been employed in other work—*e.g.*, in 1896 on the monograph 'Das Menschenhirn.'" This was a two-volume work which did much to clear up some of the most difficult parts of the morphology of the brain, *e.g.*, the structures related to the dentate gyrus and other parts of the rhinencephalon. This work included not only a study of the adult brain, but the brains of a large series of human fetuses of various stages of development were included.

Another subject which attracted Retzius was the study of the spermatozoa of various groups of animals, from invertebrates to man. The sperms of scores of species were described and figured, and considerable attention was paid to a comparison of these cells in the higher apes and in man.

Volume XV. of the "Biologisches Untersuchungen" (1910) contains the first of a series of cytological studies on the ova of various invertebrates, chiefly Echinoderms. Retzius was now sixty-eight years old and it is remarkable that at this age he should still keep sufficiently abreast of the newer developments of biological science to take up research in a field which presents so great technical difficulties. The drawings, and apparently the preparations for these first studies were made by himself, for in Volume XVI. (1911) for the first time appears any reference to the work of a technician.

The wide range of his friendship with the scientific men of Europe is indicated by the dedications of these handsome volumes. The names of Kölliker, Nansen, Cajal, His, von Ebner, Schwalbe, Waldeyer, Oscar Hertwig, and others, usually with the inscription, in "friendly veneration" adorn the dedicatory pages of his volumes. Other volumes are dedicated to various members of his family. The scientific work of Retzius received widespread recognition by his election to honorary membership in the learned societies of the chief cities of Europe and America—indeed, the catalogue of the societies to which he was elected is very similar to a list of the capitals of Europe, with Philadelphia and Washington added. Honorary degrees were conferred upon him by the Universities of Upsala (1893, Ph.D.), Bologna, Wurzburg, Cambridge, Geneva and others, and various governmental recognitions were bestowed.

In 1908 he was called upon to deliver the Croonian lecture before the Royal Society of London. He chose for his topic "The Principles of the Minute Structure of the Nervous System as Revealed by Recent Investigations." A perusal of this lecture, which is contained in the *Proceedings of the Royal Society* serves well to reveal the modesty and pleasing address of the man. In the following year he returned to England to deliver the Huxley lecture before the Royal Anthropological Institute of London. On this occasion he spoke on the "So-called North European Race of Mankind." In this lecture he took a somewhat pessimistic view as to the ability of the Nordic race whose characteristics the studies of his father and himself had done so much to differentiate, to meet modern conditions of industrial life in competition with the smaller bodied, vegetable-eating races of southern Europe. The Nordic race requires the open country and flesh for food. It is a race of warriors, administrators and farmers, not of city dwellers or workers in factories. Such are the outlines of his thesis.

Professor Keith, the celebrated English anthropologist who heard him on that occasion writes[3]

> No fellow of the Institute who had the fortune to listen to the Huxley lecture of 1909 can forget the graciousness, courtesy and modesty of the lecturer, nor the pleasant memories which his wife and he left with his audience.

In summing up his scientific work we may again quote Keith who says

> He did more to enrich the literature of physical anthropology, anatomy, and physiology than any other man of his time. His numerous monographs deserve to be called princely, whether we consider the finish, the magnificence of their illustrations, their full and accurate record of observation, or the exactness of the methods which were employed in their production.

[3] Keith, A., Gustav Magnus Retzius, *Man,* Vol. XIX., No. 10, October, 1919.

No picture of Retzius would be complete without further reference to his other than strictly scientific activities. In 1884, as already noted, he became head editor of the *Aftonbladet.* His early literary work had been excellent preparation for this position, which he filled for three years. Numerous contributions on politics, sketches of his travels, and biographical sketches of scientific men, foreigners as well as his own countrymen, were made by him through the columns of this daily paper during this period, and also after he relinquished his editorial duties.

Retzius made numerous journeys to the various countries of Europe, and also to other continents. The benefit of these travels he shared with his countrymen, so far as was possible through the sketches to which reference has already been made, and through a volume of 372 pages, which appeared in 1891, entitled "Pictures from the Nile Country." Another volume of 96 pages appeared the following year on "Pictures from Sicily." In 1893 and 1894 appeared a series of 34 letters in the *Aftonbladet,* called "Pictures from North America."

Reference has already been made to the early literary work which through the pressure of his scientific researches was neglected for a number of years. That Retzius continued his interest in poetry, however, and in music, despite his expressed diffidence in understanding the latter, is evident in the publication in 1911 of a 242-page octavo volume of poems, and in the preparation by him of two cantatas. The first of these appeared in 1898 on the occasion of the celebration of the memory of Jacob Berzelius, for many years the Nestor of modern chemistry in the early part of the nineteenth century. The second cantata was produced at the celebration under the auspices of the Royal Academy of Stockholm, of the 200th anniversary of the birth of Linnæus, May 25, 1907.

Retzius's greatest interest, however, aside from his researches, apparently lay in the same direction to which we are at present turning our thoughts, namely, in the lives and personal history of the makers of science. Some fifty biographical sketches of scientific men, for the most part workers in the biological sciences, were published by him. Most of these were published in the *Aftonbladet,* in an effort to make more widespread the gospel of scientific work. In connection with this phase of his intellectual activities he became interested in the anatomical and physiological writings of Emanuel Swedenborg, to which he gave considerable study. For a time, including the year 1903, he served as president of the Swedenborg committee of the Swedish Academy of Sciences, whose purpose was to bring to light some of the forgotten discoveries of the mystic genius whose writings they studied.

To give in the briefest form possible a comprehensible glance at the activities of Retzius, as evidenced by his published work, we may divide his publications into five groups. Group 1, representing his work in natural science, includes 127 titles, many of which represent one or more large volumes. Group 2, which represents his studies in biography, includes 50 titles. Group 3, his travel sketches, were published under 24 different titles. Group 4, poems and literary translations, is represented by 5 titles, and Group 5, which includes his political essays and miscellaneous contributions, includes some 35 titles. To these, numbering 244 contributions in all, should be added several volumes which were edited and published by Retzius, such as the ethnological writings of his father, and two volumes which included letters of his father, Anders Retzius, to various men. These constitute his bibliography to the year 1914.

In addition to membership in the leading scientific societies of Europe and America, and the bestowal of honorary degrees by a number of universities, Retzius also received recognition as the recipient of various prizes from scientific bodies.

He died on July 21, 1919, full of honors and of years, for he was seventy-seven years of age. He had seen the science of anthropology established, and had made important contributions to it. Likewise he had taken an important part in the development of many phases of histology, and had been one of the pioneers in the study of the nervous system by modern methods. It appears likely that in the histology of the nervous system, especially, the name and contributions of Retzius have found a permanent place.

THE PHYSICAL SPENCER

By Dr. JAMES FREDERICK ROGERS

NEW HAVEN, CONN.

Men's characters must be in part determined by their visceral structures.

NO modern writer has preached the gospel of health more earnestly than Herbert Spencer, and no other man has had so wide a hearing, though his "Physical Education," like many another sermon, has been more heard than heeded. The pathetic exclamation which it contains—"What is the worth of distinction, if it has brought hypochondria with it?"—indicates that the author's own experience is the source of his eloquence.

What was the experience out of which this great essay sprang? Fortunately the intimate history of the great thinker (the worth of his philosophy is again recognized after the usual reactionary eclipse) was minutely chronicled and analyzed by the philosopher himself and one has but to cull from his autobiography the items bearing on the subject of his bodily history.

From his pathetically minute investigations of his ancestry, one learns that back of his parents his fore-bears were physically commonplace. Of his father he writes, "though not robust in the full sense, he had a constitution which was well balanced and capable of considerable endurance, as witness the fact that he, when a young man, in company with his two brothers, walked sixty miles in a day. Standing six feet when shod, he was noteworthy for a well-built figure and a carriage which invited dignity and grace in a degree rarely equaled." However, the father's health gave way when Herbert was a child and he suffered from severe headache and extreme irritability and was compelled to abandon his work of teaching. In physique, his mother "was not of so fine a type, and the constitution, though fairly well balanced, was by no means so vigorous."

Spencer was the first of nine children and the only one to survive beyond early infancy. As the only surviving child, Herbert's own health was a matter of some concern. He was not pushed into school at the usual age and he had the inestimable advantage of life in the country. "The majority of my activities were those of the ordinary school boy who, on Saturday afternoons and the like occasions of leisure, is commonly given to country rambles and the search for hedge-side treasures. During my early years the neighboring regions of Binaston and Normanton were explored by me in all their details, every hedge becoming known in the course of expeditions, now in the spring seeking birds' nests, now gathering violets or dog-roses, and later in the year collecting sometimes mushrooms, sometimes blackberries, sometimes hips and haws, crabapples and other wild products. . . . Of all the occupations, however, to which the holidays were devoted, I delighted most in fishing. . . . Many happy half-days, and, during the mid-summer holidays, many whole days, were spent on the banks of the Derwent." He became an enthusiastic collector of insects. "Saturday afternoons and other times were spent in exploring banks, hedges and trees, in search of larvæ; and I made in the course of time a considerable collection of moths, butterflies, dragon-flies, and beetles."

That there was a large fund of energy, and very much at the command of its possessor, is indicated by the incident related by his father that in his ninth year Herbert took a journey (without his mother's knowledge) of seven miles to visit his father, and, in doing so, ran the greater part of the way.

That the body of the boy was, at the age of twelve, dangerously under the thumb of the so-called higher faculties and that the nervous system was strenuously assertive, are evidenced by the fact that, having entered the glamorous land of fiction, he often browsed in it all night, reading in bed "till the birds were singing in the morning. After a time this transgression was discovered, and my mother adopted the precaution of coming to my room to see whether the candle was out. But I was not thus to be balked of my midnight gratification and soon out-maneuvered her. Close to my bedside was a fixed corner cupboard; and habitually, when I heard her step on the stairs, I leaped out of bed, put the candle still burning into this cupboard, got into bed again and pretended to be asleep, until she, thinking all was as it should be, retired. Whereupon I brought out the candle and resumed my reading."

"As I had not been injudiciously pressed or considerably taxed during childhood and afterwards, my health was, or had become, quite satisfactory. I can recall nothing more than a few days' illness from one of the disorders of childhood; and on the whole my vigour, though not great, was considerable. There seemed to be then, and continued thereafter, a constitution distinguished rather by good balance than by great vital activity. No spontaneous overflow of energy was exhibited—no high pressure of steam; and hence a certain reluctance to exertion in the absence of a strong motive. Nevertheless, there was a large margin of latent power—a good deal of 'bottom' as the sporting people call it. In feats of strength I do not remember any superiority, except in running I was more fleet than any of my school fellows. This may have been associated with an unusual length of limb, by which in boyhood I was characterized.

"Respecting those emotional characteristics directly associated with the physical, I may note that on the whole I was decidedly peaceful. This may have been in part due to the trait which I inherited from my father—a great intolerance of painful feelings, either physical or moral." . . . However, "when sufficiently aroused by anger, no considerations of pain or danger or anything else restrained me."

Early in his thirteenth year Spencer was taken a hundred and twenty miles from home to his uncle's school at Hinton. Disagreement with a fellow student, homesickness, and rebellion against his exile, were too much for him, and on the tenth day he arose at six o'clock and set out for home, "reaching Bath in little more than an hour, and buying a penny roll just before leaving the city on the other side. I took the Cheltenham road; and, as I ascended the long hill and for some time afterwards, kept glancing over my shoulder to see if I was pursued. Presently, getting on to the high broad back of the Cotswold Hills and increasing my distance from Hinton, I ceased to fear that I should see the pony-carriage coming when I turned my head. But now as I walked on under the hot sun, I began fully to perceive my forlorn state; far away from any one I knew, without possibility of going back, with scarcely any money, and with an immense journey before me. No wonder I burst into tears from time to time as I trudged on. However, my speed, judging by the result, was not much diminished by the occasional fits of grief. Pursuing the monotonous road, varied only by here and there a cottage or a toll gate, I came in the afternoon to the end of the highlands and descended into the Strond valley; walking through its picturesque scenes in a widely different mood from that in which I had seen them a few weeks before. Reaching Strond between five and six, I remember asking a man on the other side of the town, which was my way to Cheltenham. He pointed out the way and said, 'But you are not going there to-night, are you?'

He would have been greatly astonished to hear that I had already walked from five miles on the other side of Bath.

"I could not sleep a wink at Cheltenham. The physical excitement produced by walking 48 miles, kept me tossing about till it was time to rise. Next morning, however, I early started off again, undismayed by my bad night. I got a ride out of Cheltenham for some two miles in a cart; and then resumed my weary walk, seeing from time to time the Malvern Hills, which, when I first caught sight of them the previous evening, had given me a thrill of pleasure as being old friends. Mile after mile was traversed during the sultry August day, along roads thickly covered with dust—through Tewkesbury and Worcester, on to Droitwich and on to Broomsgrove, which I reached and passed in the evening. I intended to walk that night to Birmingham, but an occurrence deterred me. While resting some miles beyond Broomsgrove, I was accosted by one of those wandering Italian image sellers, common in my boyhood—men who went about carrying on their heads boards covered with plaster casts, and calling out 'Finees!' This man sat down by me; and when I walked on he joined me. After a time he pulled out a large pocket knife with a blade of some eight inches long or so, and spoke of it admiringly. This, as may be imagined, made me shudder. I do not suppose he meant anything; but still his act suggested the thought that he might murder me. Presently we arrived at the little inn on the Lickey called the Rose and Crown, and I asked for a bed. Luckily they let me have one, and to my great delight they would not let the Italian have one. He had to go on."

"That night, like the preceding one, was sleepless. The exertion of walking about the same distance as before (for I believe from Cheltenham to the Rose and Crown is 49 miles, and deducting the 2 in the cart leaves 47) had maintained that feverish state of body which always keeps me awake. Next morning after a few miles walking, I came up with one of those heavy wagons, common in the days before railways, carrying goods between chief towns—wagons now no longer seen—great lumbering vehicles with large hoods to them. I made friends with the wagoner; and he let me ride on the soft straw as far as Birmingham, where he stopped. Thence I walked on to Lichfield. At Lichfield I happened to be passing the chief hotel just as the Derby coach drew up; and, getting hold of the coachman, told him my story. No doubt he saw in my worn face and parched lips how much I had been suffering. He took pity on me, and, the coach having plenty of room, let me ride for nothing. I asked to ride as far as Burton. When we reached Burton I offered him the few coppers I had left to let me go on. He, good fellow, refused to have them, but allowed me to keep my seat; and so I reached Derby about 3 o'clock in the afternoon of Saturday, having left Hinton on Thursday morning. That day I had walked not more than 20 miles, if so much.

"Here, before passing to subsequent incidents, I may remark on the physical effects of this escapade. It can, I think, scarcely be doubted that my system received a detrimental shock.

"My uncle too, at the same period comments on my dulness and failure of memory. Certainly this last trait must have been very marked. Not only have I absolutely forgotten some books I read at that time, but, until perusal of my letters proved that I had read them, I did not know that I had ever seen them. Was not growth the cause? If excess of muscular effort, as in a pedestrian tour, is apt to leave behind inertness of brain, which for a time makes mental work difficult, it is reasonable to suppose that an unusual draft upon the resources of the system for building up the body, may, in like manner, leave the brain inadequately supplied, and cause feebleness in its action.

"It is worth inquiring whether in such cases there is not produced a simultaneous moral effect. If there is such an effect an explanation is yielded of the fact which the correspondence of the time proves, that there occurred a deterioration in my relations to my uncle and aunt. I got out of favor with them, and I was dissatisfied with my uncle's treatment of me. Is there not reason to think that rapid growth may temporarily affect the emotional nature disadvantageously, in common with the intellectual nature? As in children failure of cerebral nutrition, when caused by inactivity of the alimentary canal, is commonly accompanied by ill-temper; so, it seems not improbable that when the failure of cerebral nutrition is caused by the demands made for increase of the bodily structure, a kindred result may be entailed. Conditions which bring about a defective supply of blood to the brain, tend to throw the higher powers out of action while they leave the lower in action; the later and less evolved faculties feeling the effects of an ebb-tide of blood, more than the earlier and fully evolved ones. Such a relation, if proved to exist, should be taken into account in the treatment of young people."

He completed his student days at Hinton in his sixteenth year, and reviewing its results he says: "Certainly it had been physically advantageous. I returned to Derby strong, in good health, and of good stature; my ultimate height (not then reached, however), being five feet ten inches. I had doubtless benefited both by the rural life and by the climate, which is bracing."

The tendency to insomnia by which he was later so afflicted was already present, for of the next year he recalls that, with a fishing trip in prospect, he "retired to bed somewhat early with the intention of starting at daybreak. Even in those days much excitement kept me awake; and the forthcoming gratification so filled my thoughts that for hours I vainly turned from side to side. All the while the room was partially illuminated by the light of a full moon, which penetrated the wide curtains. Somewhere about three o'clock the thought occurred to me, Why lie here tossing about? The thought was forthwith acted upon. I got up, dressed, sallied out, walked by moonlight to Swarkstone, five miles off, and began fishing by moonlight."

At nineteen he walked from five to ten miles a day, was a good skater and fond of boating and horseback riding, but although his health was, on the whole, satisfactory, he was conscious of the working of the machinery, as is evidenced in a letter of his nineteenth year:

"I have been quite idle and stupid lately. I expect I am beginning to fill out a little and that all the energies are directed to bodily development. I do not recollect that you gave me your opinion whilst I was in Derby upon one of the questions I asked you. To what extent is it expedient to force the mind against the inclination? I should like to hear what my uncle Thomas says upon this head. It seems to me to be rather important to be able to distinguish between idleness and mental debility. . . ."

He was evidently making careful, much too careful, note of the influence of bodily states on mental activity, and, in the following year, after a time of hard work, he says, "The effect of the over-exertion showed itself in depression of spirits and a constant feeling of dissatisfaction with myself, and a more than usual repetition of the fear (which I have occasionally felt for the last four or five years) that my mind is not so vigorous or acute, nor my memory so retentive as it once was."

He concludes, after noting his increase in weight to 150 pounds, that this, in itself, was the cause of his present stupidity.

His engineering labors on the Birmingham and Gloucester

Railway would be called extremely strenuous nowadays. "We were at work on Tuesday from 8 A.M. to 3 A.M. next morning and every other day in the week from the same hour to 12 at night, and even Sunday was not exempt from its portion." It is little wonder that he found his eyes "beginning to be affected. . . . For the first time in my life they began to ache when used for several hours in drawing."

The following year he found it advisable to quit this work and on his return home "my old schoolmaster expressed his satisfaction that I had not come back to the paternal roof injured by dissipation, as many young men do."

As sub-editor of *The Economist* Spencer found it took him "a week to become so far inured to the eternal rattle of the Strand as to be able to sleep. . . . for some time I suffered in general health from noise" and the close atmosphere of the office. "Having at length caught cold three times within two months, I thought it was time to make some change." He removed to better living quarters with a longer walk to work, and he also made a radical change in diet. He became a vegetarian.

Of this latter move he writes his mother: "As I have felt no inconvenience during these first few weeks, I do not suppose I shall now do so. I think I have felt the cold more keenly than I should otherwise have done, and I find others who are trying the experiment make the same complaint. I believe, however, that this result is merely temporary. Meanwhile I am in all respects well and strong."

Commenting in his biography he says: "From the phrasing of these statements it is clear that I was willing to persist in vegetarianism, had I been encouraged to do so by further results. My scepticism was first aroused, however, by the fact that after six months' abstinence from animal food, our friend Loch gave evidence of a lowered condition. His voice had become extremely mild and feeble, and he had partially lost power over one of his feet in walking. Writing, as it seems from my father's dating, towards the close of May (for I had not dated the letter myself), I said—'I have about decided to give up the vegetarianism, at any rate for the present. I think this relaxation under the eyes is due to it.' The clearest evidence, however, that I had been suffering, was disclosed afterwards. I found that I had to re-write what I had written during the time I was a vegetarian, because it was so wanting in vigour."

His work upon "Social Statics" was already resulting in insomnia.

In his thirty-third year Spencer made a pedestrian tour into Switzerland. Disastrous effects resulted, or developed at this time.

"Years before I had read Andrew Combe's work The Principles of Physiology applied to the preservation of Health, and had duly accepted the warning given by him against excessive exertion on the part of those who, having previously led sedentary lives, attempt feats of walking and climbing. Yet, aware as I was of the possible mischiefs, I transgressed: not, however, as it seems, without excuse. In the above-named letter written on the Faulhorn, after urging my uncle to see Switzerland, I went on to say—

"'There is however great temptation to do too much. The difficulty of getting tolerable accommodation save at certain places, often induces one to go too far, and spite of the feats which the Swiss air enables every one to do, Lott and I overdid ourselves a few days ago, in spite of my previously made resolution to avoid any excess of exertion. However we shall be more resolute in future.'

"Of three excesses in walking which I recall (the last being subsequent to the date of the above-named letter, notwithstanding the resolution expressed in it) two were caused by misleading statements contained in Murray's Guide. This led us to arrange for stopping at places which, when we saw them, we instantly decided to avoid at the cost of two or three hours' more walking along rough roads and in partial darkness; previous experience having proved that nights made sleepless by fleas were the alternatives.

"These details I set down as introductory to the statement that within a few days of my return to London, there began signs of enfeebled action of the heart. There was no mental cause. As said in a letter to my father, while in Switzerland 'I cultivated stupidity assiduously and successfully;' and after my return it was some weeks before I got seriously to work."

"Two distinguished physiologists have at different times assured men that the heart can not be overtaxed; but, authoritative though their opinions are, I have found acceptance of them difficult. Among reasons for scepticism are these:—First, the improbability that there are no foundations for the many assertions that extreme exertion, as in rowing matches, sometimes leaves behind a long prostration. Second, there is the unquestionable fact that during states of debility the heart is easily overtaxed; the implication being that if, during an abnormal state, its limit of power may be exceeded, it may be exceeded during a normal state. Third, the truth that other organs have limits to their powers which can not be over-passed without damage—damage sometimes ending in atrophy—seems scarcely likely to fail in the case of one organ alone. Fourth, such an exception does not seem reconcilable with the hypothesis of evolution; for how, by either natural selection or by direct adaptation, can any organ have acquired a never-used surplus or strength?

"Be the interpretation what it may, however, here is a fact, that immediately after my return from Switzerland, there commenced cardiac disturbances which never afterwards entirely ceased; and which doubtless prepared the way for the more serious derangements of health subsequently established."

He tried hydrotherapy and the results are noted in a letter:

"I have nothing very definite to tell you, further than that on the whole the palpitations seem to be gradually diminishing and do not generally attract my attention even at night; although still more or less perceptible then, when I purposely direct my attention to them. In other respects I am much as I was. No great effect either one way or other seems to be produced by the treatment, so far as I can judge by my feelings. But being on the whole very well, I don't know that I have any right to expect any very marked results."

While writing his Psychology at thirty-five, there appeared increasing storm clouds of ill health.

"I spent something like five hours a day in writing: beginning between nine and ten, continuing till one, pausing for a few minutes to take some slight refreshment, usually a little fruit, and resuming till three; then sallying out for a country walk and returning in time for dinner between five and six. I had often warned my friends against overwork, and had never knowingly transgressed. Five hours per day did not seem too much; and had there been no farther taxing of brain, no mischief might have been done. But I overlooked the fact that during these months at Derby, as during all the months since the preceding August, leisure hours had been chiefly occupied in thinking. Especially while walking I was thinking. The quickened circulation consequent on moderate exercise, produced in me then, as always, a flow of ideas often difficult, if not impossible, to stop. Moreover the printers were at my heels, and proofs coming every few days had to be corrected; tasks which must have occupied considerable portions of my evenings, Practically, therefore, the mental strain went on with but little intermission.

"That mischief was being done ought to have been clear to me. A broad hint that I was going wrong was this:—One of Thackeray's stories—The Newcomes I think it must have been —was in course of issue in a serial form. When a new part came out I obtained it from a local library, and, reserving it till the evening, then read it through. As often as I did this I got no sleep all night, or, at any rate, no sleep till towards morning. My appearance too should have made me pause. A photograph still existing, which was taken during the spring, has a worn anxious look; showing that waste was in excess of repair. It seems strange that such knowledge as I had of physiology, did not force on me the inference that I was injuring myself, and that I should inevitably suffer.

"But giving no heed to these warnings I thoughtlessly went on without cessation; eager to get the book done, and, I suppose, hoping that rest would soon re-establish my ordinary health. Towards the end of June there remained but three chapters to write. These were written elsewhere.

"One morning soon after beginning work, there commenced a sensation in my head—not pain, nor heat, nor fulness, nor tension, but simply a sensation, bearable enough but abnormal. The seriousness of the symptom was at once manifest to me. I put away my manuscript and sallied out, fishing-rod in hand, to a mountain tarn in the hills behind the hotel, in pursuance of a resolve to give myself a week's rest; thinking that would suffice.

"Next day came a walk to Beddgelert. That place being much shut in, proved, as I might have known it would, very enervating. After two days I left for Carnarvon and afterwards for Bangor; taking up my abode at Garth Point for a week. While there I managed to finish everything but the chapter on 'The Will' with which the work ends.

"The close of the month found me back home; where this last chapter was completed under great difficulties. I alternated between house and garden: writing a few sentences and then pacing up and down for a time to dissipate head-sensations—a persistence in physiological wrong-doing which brought on further serious symptoms."

And now began that pursuit of health which proved to be life-long and fruitless. At thirty-six he was "unable to bear more than a few minutes conversation." He gave up mental work, walked ten to twelve hours a day, and went on fishing excursions with results in better sleep. He noted that his higher "other-regarding faculties" were impaired by his nervous break-down,—that he was lacking in judgment and more emotional than was natural.

"Both then and afterwards, my sleeping remained quite abnormal. A night of sound sleep was, and has ever continued to be, unknown to me." He averaged four to five hours unconsciousness—"in bits," and for twenty-five years had no sensation of drowsiness. At his best he "never got beyond three hours' work a day without mischief."

Better and worse, but with almost constant introspection, is the health tale from now on. His comments on his condition, if tiresome, are often valuable. Speaking of the results in mental states, he says:

"Speaking generally, each step in mental evolution results in a faculty by which the simpler pre-existing faculties have their respective actions so combined that each aids in regulating or controlling the others, and the actions of all are harmonized. Each higher judgment differs from lower judgments in that it takes account of more numerous factors, or more correctly estimates their degrees of relative importance; and is thus a more complex mental act. And similarly, among the higher feelings, all relatively complex, the highest are those which stand related to lower ones as moderators; their moderating function being effected by combining within themselves representations of these lower feelings, no one of which is allowed to occupy more than its due share of consciousness, and therefore is not allowed unduly to sway the conduct. Manifestly, by their very natures as thus understood, these highest intellectual and emotional powers, by which well-balanced judgments are reached and well-balanced feelings maintained, require more than all others, a full flow of nervous energy—a flow sufficient to simultaneously supply all the numerous structures called into action. Consequently, they, before all others, fail when the tide of nervous energy ebbs. Defect of coordination is shown intellectually in erroneous judgments concerning matters where sundry circumstances have to be taken into account, and emotionally in the ill-controlled feelings which lead to impulsive expressions and deeds. The primitive and deeply-rooted self-regarding faculties, which tend ever to initiate antagonisms, are scarcely weakened during states of prostration; while the other-regarding faculties, relatively modern and superficial, and soon paralyzed by innutrition, fail to check them. And then beyond the direct evils which the nervous subject brings on himself by such failures, there are the indirect evils that result from misinterpretation of his character."

(*To be concluded*)

PRESENT ECONOMIC AND SOCIAL PROBLEMS[1]

By Dr. DAVID JAYNE HILL

WITH the exception of certain formalities of procedure, the Great War is an affair of the past. The problems of repairing its ravages and paying its cost still confront us. Although the solution of these problems bears more heavily upon the European nations than it does upon the people of the United States, our obligations are not inconsiderable, and we are finding that the war and its results have profoundly affected our economic and social existence as a nation.

Among the issues that appeal most strongly to our interest and our intelligence is the question how we may most effectually contribute to securing in the future international peace; or, to express it differently, how we may prevent future wars?

There is, I think, no difference of opinion among thoughtful men anywhere regarding the desirability of avoiding future sanguinary conflict; which can only determine whose will shall temporarily prevail, and can therefore never furnish a basis for permanent peace. War can be prevented only by removing its causes.

When we examine into the etiology of war, we discover that not all wars are wrong; from which it follows that the enforcement of peace can not always be right. This results from the fact that war is resorted to from two opposite motives: on the one hand, a sense of intolerable injustice or oppression which should be resisted; and, on the other, a spirit of domination and lust for conquest which, regardless of principles of equity, attempts to subdue and expropriate others.

The remedy for the former cause of conflict is the establishment and maintenance of such institutions of justice as would prevent oppression. The problem is fundamentally one of jurisprudence, and its solution is a state of security under just and equal laws. This could be perfectly attained by voluntary cooperation, if the will to attain it were universal.

Unfortunately, this will is not universal. There exists among men, both as individuals and as nations, a predatory disposition, a desire to despoil and to take possession of

[1] Address of the Chairman before the Section of Social and Economic Science of the American Association for the Advancement of Science, St. Louis, December 29, 1919.

another's property. This predatory disposition is a cause of war that can never be eradicated except by the creation of a power of repression strong enough to arrest it by rendering it dangerous and unprofitable, and eventually to overcome it by inducing modes of life in which it will be outgrown. Such means are found in all civilized communities in the form of a police force, and among nations in the form of military organization. So long as any considerable residue of the predatory instinct remains in men—and we see few signs of its extinction—both of these forms of repression will be necessary if peace is to be maintained and justice enforced. The problem of peace, therefore, reduces itself to two measures: (1) the improvement of legislation, municipal and international; and (2) the enforcement of law.

Methods for the enactment and enforcement of municipal law have been relatively well worked out in the most civilized countries, yet with much still to be desired with regard to the administration and the cost of justice; to the end that all, the poor equally with the rich, the weak equally with the strong, may be able, in fact as well as in theory, to obtain the vindication of their rights. In international relations, for obvious reasons, since the state has been reluctant to place itself under the dominion of law, there has been less advance toward the realization of justice.

The primary obstacle, we have been accustomed to think, has been the imperialistic spirit, which is essentially a tendency on the part of the powerful states to exploit and dominate the weaker nations and peoples. In the Great War we were led to believe that we were fighting to destroy that spirit. Several of the great empires, as a result of the war, have been virtually destroyed, at least so far as monarchical autocracy is concerned. There has been a general toppling of royal thrones. Two German Kaisers, the Czar of Russia, and the Sultan of Turkey have been shorn of their power. It remains to be seen, however, whether the imperialistic spirit has been really crushed; for this does not inhere in monarchs only. Even alleged democracies have in the past been imperialistic in their foreign policies, and some of the small newly constituted or newly consolidated countries only recently rescued from despotism are already manifesting a spirit of aggressive nationalism that forebodes if continued inevitable conflict between them, not to mention the ambition of some of the Great Powers that were allied with the democracies in prosecuting the war.

The real test of the abandonment of imperialism is a willingness to accept as a basis for international legislation the inherent rights of all responsible states, without reference to their power or magnitude. Although this was one of the alleged intentions of the Allied and Associated Powers in the Great War, coupled with the proclamation of the self-determination of all peoples as one of its purposes, I think it can not be affirmed that the treaties of peace exhibit any marked progress in this direction. On the contrary, the keynote of the Treaty of Versailles is the creation of an imperial syndicate composed of five Great Powers, with others distinctly secondary and subordinate to them, and a distinct repudiation of an attempt to reestablish the Law of Nations on the basis of common consent and the equal juristic rights of all sovereign states. In the presence of this fact we can not affirm that the Covenant of the League of Nations is a final solution of the problem of peace.

In the Treaty of Versailles the emphasis is not laid upon the principles of jurisprudence as the basis of international relationship, but upon the enforcement of peace by military power. The primary problem before the conference at Paris was a victor's peace. The Central Powers had to be placed under penalties and those penalties had to be enforced. The atmosphere in which the League of Nations was created made it the first purpose of its being to punish a conquered enemy. The League was, therefore, bound to have a military character. It was, in effect, an alliance against the possible future behavior of a group of defeated Powers. This, it was asserted, was necessary, in order to execute the treaty of peace. Its aim was to maintain by force a status created by force.

Such a compact, however necessary at the conclusion of a war, is by its nature not only different from a permanent organization of friendly nations, on equal terms, for the preservation of peace; it was incompatible with the essential idea of such an organization, the natural basis of which would be equality and mutual confidence. The peace imposed by the Treaty of Versailles was not a peace based on understanding inspired by a common purpose and a community of interests; but a peace based on force, inspired by distrust and a conflict of interests.

It is impossible to consider such a compact as the ultimate solution of the problem of perpetual peace. A peace that has to be enforced by arms is not a true peace, but only a temporary appearance of peace. Beneath this appearance there is hidden the spirit of revolt, only waiting for an opportunity to assert itself in open conflict. It was, no doubt, necessary that this specific settlement should be punitive. When executed it would constitute a memorable lesson. But true peace is not made by war. It may issue from it, but it requires a new spirit and a new process. It must be based on other conceptions. It is only through some larger apprehension of mutual advantage, that is, through the acceptance and application of definite and universal principles of equity, that true peace can be attained. The effective formula, therefore, is not the enforcement of *peace*, but the enforcement of *law*. In this, and in this only, is to be found the pathway to peace; which is not an end in itself, but the concomitant of a mode of existence made tolerable by the establishment of equitable conditions.

Even under a rule of just and equal laws, war may still be possible; for, so long as lawbreakers exist, nations may be inspired to military action in violation of the law. It is then the vindication of the *law*, rather than the military enforcement of *peace*, that should be made the object of international association.

The advocates of the Covenant of the League of Nations will, no doubt, contend that this is really the purpose of the League. Unfortunately, this is not as evident as could be desired. There is in the Covenant a large provision for the future use of force, and especially a great stress upon the occasions when it is to be employed, but the relation of military action to any defined principles is obscure in this Covenant. There is no provision for the further improvement or clear formulation of international law. There is no strict obligation to obey it. There is no agreement to enforce it. For the preservation of territorial boundaries there is great solicitude and almost excessive provision, regardless of the manner in which possession has been acquired. For the execution of the penalties imposed upon Germany and other Powers—I do not raise the question of their justice—there is in the Treaty of Versailles elaborate provision. But a proposal to reexamine, revise, and improve the Law of Nations, and then strictly to obey it, was not only not accepted, it was distinctly disregarded.

In this respect the aims and ideals of the free nations, especially of the United States of America, were not embodied in the Covenant of the League. To this extent, therefore, whatever may be its merits, the League is, in effect, an alliance of Great Powers for the international control of others, rather than a society of free nations for the establishment of peace through justice.

I do not for a moment question the necessity of a combination of the Allied and Associated Powers to enforce upon the nations that were the aggressors in the Great War. The safety of civilizations demands this. With respect to the past this was to be expected and desired, but it by no means places the peace of the world on a secure foundation, for the reason that it is primarily a compact based on force and not on the inherent rights of nations. As a combination of force, it is subject to the vicissitudes of all military combinations. It may disintegrate when its primary object is attained, or even before that; and it is liable to be confronted with some other combination of a like character and eventually of greater strength. A mere preponderance of power can not be expected always to endure; and in so far as it is merely that, it can not claim any moral or legal authority which an opponent might not equally claim. To those who say, "The existing frontiers which we have established must be consecrated for all time," another group may with equal authority say, if it possesses the power, "These frontiers are unjustly established, and we propose to change them as we think right."

Before the peace of the world can be definitely secured, there must be such an evolution of national demarcations as have in themselves the elements of equity. But the most important observation to be made regarding a League of Nations is that its whole value consists in the national unity and efficiency of the nations that compose it. It is to the character of the component nations, therefore, that we must look in forming an estimate of the future of such a League. As a people, our first thought should be for the security of our own national existence, unity, authority, and independence. Entrance into any international combination that would destroy or deteriorate those qualities would be disastrous to ourselves as a people and the gravest misfortune that could befall the world. We must not permit ourselves as a nation to be either Prussianized or Russianized.

It is timely, therefore, that we should look to our foundations as a nation. We must first of all recognize the fact that our conception of national life is *sui generis*. Our Constitution is the outgrowth and expression of a new appreciation of the value and the possibilities of the human individual. We began our national existence by solemnly guaranteeing the right of every citizen to life, liberty, and the pursuit of happiness. Our political system was intended to protect him in the exercise and preservation of those rights. Here is a solid foundation on which to build our social and economic structure, and one on which we may readjust it when it is shaken, as it has been, by the storms of war.

Men are speaking much just now of "reconstruction," and there are those who would tear up all foundations in the process. They would disintegrate the nation, and merge its energies and resources in a vague internationalism. Some would reapportion the proceeds of past industry, prudence, and enterprise; if necessary, even by violence. Others would accomplish the same result by the destruction of our political institutions. There are serious advocates of such a contradiction in terms as "constructive anarchy."

There is at this time more than the usual need of recognizing the fact, that there can be no sound internationalism that neglects the *quality* of nations. It is futile to merge our energies and resources in a mass of quarrels, uncertainties, and contradictions. The first essential of our usefulness to the remainder of mankind is that we should ourselves be free, strong, united, and sure of our own future. It would be folly to bind ourselves by solemn engagements to the performance of unknown tasks. There is nothing in our freedom that would prevent our loyalty to any obligations we have assumed by our participation in the Great War. We shall never stand by in silence and indifference if any unprovoked attack should be made by our former enemies upon our allies and associates for reasons growing out of the strife in which we have been engaged. In many respects their cause is our cause, and their safety our safety. But with disputes arising from a conflict of ambitions, with future quarrels engendered through expectation of our support, with the disposition of some nations to dictate the policies of others, with which we are not concerned, and with plans for the partition and exploitation of defenceless peoples, we may wisely declare our intention to have nothing to do.

There will, however, be a large part for us to play in the sphere of international relations. We can stand for law, for justice, and through them for peace, by our own conduct, by our influence, and by leadership in realizing our inherited ideals. To do so effectively we must solve some pressing domestic problems. In this, the members of this association, and especially of this section, should perform their part.

Your committee has endeavored to state some of those problems and has sought to induce competent authorities to discuss them. In this we have been to some degree successful, notwithstanding difficulties to be overcome, and we take this occasion to express our appreciation of the responses we have received.

The most urgent economic questions of a domestic character center about the productivity of American industry and our financial relations with the rest of the world. The war has greatly dislocated our industrial processes. The diversion of our energies as a people from the pursuits of peace to the exigencies of military organization and efficiency has created a shortage in the normal production and distribution of commodities, abnormally increased wages in most forms of manufacture and food industries, and thereby greatly augmented the cost of living. This has been further accentuated by our unprecedented exportation of the necessaries of life, thus further augmenting prices at home. Finally, in return for these exports we have thus far either received no remuneration—many of these commodities having been free gifts or sold on credit—or we have received in exchange money rather than commodities, thus affecting the balance of trade and the value of bills of exchange to a point where, unless some remedy is found, it will be practically impossible for European countries to make purchases in the United States; for they can not pay our prices when a pound sterling is worth only $3.75, a franc only 9 cents, a lira still less, and a mark only a little more than 2 cents.

We must, therefore, on the one hand, increase our productivity, in order to reduce prices; and, on the other, find some method of stabilizing foreign exchange, or we shall still further heighten the cost of living and lose our trade in Europe.

The question of increased productivity depends largely upon the harmonious cooperation of the two great factors of production, Labor and Capital, and also on the spirit of enterprise which is necessary to unite them and render them fruitful. Disagreements regarding the terms of this cooperation have already menaced the country with a total paralysis of steam-driven manufacturies as well as the cessation of all means of transportation, which, if rendered actual, would mean the ruin of the country. Behind these omens of a possible industrial paralysis there has seemed at times to be very imperfectly concealed sinister purposes of radical political change, foreboding the expropriation of private property and control by the red hand of anarchy.

To meet and counteract these movements and tendencies, various remedies have been suggested, some of them almost as dangerous as the evils to be overcome. The time seems, therefore, to call for very serious study, from many different angles, of two fundamental problems: (1) What is the true basis of the relation of Labor and Capital? and (2) What is to be done in the sphere of taxation and finance?

With regard to the first of these problems, it would seem that little progress can be made without a guarantee of fulfilling a contract; which raises the question, how far reciprocal responsibility on the part of the contractants is an essential basis of collective bargaining; and where a third party, the public, is directly interested in a public service, like transportation, the question, if the continuity of it should ever be interrupted by a strike to increase wages. It is timely also to consider the effect upon our American standards of living to be expected from an attempt to internationalize labor; the relation between the labor supply and immigration; and, finally, the railway situation as a concrete case involving the application of all the solutions that may be available.

The financial problem quite naturally presents itself under two rubrics: (1) What are the duties, responsibilities, and interests of the United States with reference to the financial obligations and conditions created by the war? and (2) What are the available and as yet unutilized methods and means of raising revenue for the support of the government in the discharge of its obligations?

Whatever may be the degree of success or failure of your committee in formulating these subjects for discussion, it can hardly be asserted that it has failed to suggest a sufficient amount of pabulum for the present annual meeting. If the speakers who have accepted invitations to participate in the examination of these subjects are not as numerous as we had desired, we none the less appreciate the willingness of those who have consented to participate in the exposition of these pressing themes, and we entertain the hope that they will awaken a general interest that will promote serious discussion.

THE RATE OF EVOLUTION

By Professor EDWIN GRANT CONKLIN

THE results of evolution as contrasted with its causes may be considered from three different aspects which may be characterized briefly as diversity, adaptation and progress. The first concerns increasing diversification as shown in the appearance of varieties, species and genera which are no more complex in organization than the forms from which they have descended and which may be less complex; such changes which do not lead to more highly organized forms may be known as variation, speciation or diversification. A second aspect of evolution deals with increasing adaptation to conditions of life; this may or may not be associated with progressive organization or with speciation and may be called progressive adaptation. A third aspect, and most important as measured by its results, concerns the advance in organization from the simplest to the most complex organisms; this may be called progressive evolution, or more briefly progress. No doubt progressive organization, by which is meant increasing differentiation and integration has come about through diversification or speciation but on the other hand the latter has only rarely led to the former.

I. Diversity

The most evident phase of evolution and the one which has been dealt with exclusively by the experimental method is diversification. Smaller differences or variations among organisms may be classified, according to their mode of origin as (*a*) Fluctuations, (*b*) New Combinations, (*c*) Mutations.

1. *Fluctuations or Modifications.*—Fluctuations are variations whose differential causes are environmental, they come and go with changing environment; they are modifications of the soma rather than of the germplasm, of individual development rather than of heredity. They can be distinguished from heritable variations by the fact that they are not permanent. They are probably more numerous than all other diversities, their number and extent being proportional to the number and degree of the environmental changes which called them forth. They rarely if ever lead to modifications of the germplasm and are therefore of little or no evolutionary value.

2. *New Combinations of Mendelian Factors.*—The most common kind of inherited diversity is due to new combinations of inheritance factors in sexual reproduction. The segregation of genes in different germ cells and their combination in fertilization are rarely exactly the same in two instances. In the case of animals and plants where self fertilization does not occur there are usually several "contrasting characters" or allelomorphs in the parents, and the number of possible combinations of these rises rapidly with each additional pair of allelomorphs until in species crosses where there are many allelomorphs there may be as many different combinations as there are individuals in the F_2 generation. Furthermore the number of such new combinations is proportional to the number of germ cells which unite in fertilization and to the number of chromosomes in those germ cells. Therefore the rate at which such new combinations are formed must depend upon the rate of reproduction and the number of chromosomes and allelomorphs.

A certain proportion of these combinations are homozygous and breed true, but most of them are heterozygous and show Mendelian splitting in subsequent generations. Bateson says that most of the new varieties of cultivated plants are the results of deliberate crossing. This is the method which Burbank has employed with such wonderful success in the production of his "new creations in plant life." Linnean species contain many different biotypes and by crossing these many new combinations are produced, some of which may be economically valuable. If individuals showing desired combinations are interbred it is usually possible after a few generations to get homozygotes that breed true and thus a new variety or breed is established.

Such new combinations may therefore be of evolutionary value. It is probable that certain species of domestic animals and plants are of hybrid origin; among these are dogs, cats, cattle, horses, sheep, pigs, poultry, wheat, oats, rice, plums, cherries, etc. More than one thousand different plant hybrids have been described as occurring in nature but many of these are heterozygotes and do not breed true. Lotsy maintains that hybridization is the most important cause of evolution, but hybridization implies existing diversities such as dominants and recessives. Where and how did these arise? To attribute these diversities to still earlier hybridization only puts off the question of their *origin.*

3. *Mutants or Elementary Species.*—Since the publication

in 1901 of deVries' great monograph on the "Mutation Theory" the superlative importance of mutations in evolution has been widely accepted. Genuine mutants, due most probably to sudden changes in individual genes, have now been found in so large a number of plants and animals among both wild and domesticated species, that it seems probable that all inherited differences appeared *in the first instance* in this way.

The evidence is accumulating that mutations are rare only when contrasted with the relatively large number of individuals which show no hereditary variations. Wherever there are contrasting characters, or allelomorphs, and few things are more common, a mutation has occurred at some time, though it may have been long ago, by which these allelomorphs became different. Wherever there are breeds, races, or stocks there is evidence, *ex hypothese,* that their constant differences were established by one or many mutations occurring at some time or times in the past.

The rate at which mutations appear seems to differ greatly in different species, but it is suggestive that they are found most abundantly in species which have been studied most thoroughly, and it is probable that they are of much more frequent occurrence than is now known. The largest number of mutants which have been found in any species under conditions of accurate observation and experiment are in the pomice fly *Drosophila melanogaster,* and one of the most frequent types of mutation in this species is the appearance of lethal factors which cause the early death of individuals which receive this lethal from both parents.

Muller and Altenburg find in *Drosophila* that the ratio of lethal mutants to the normal condition in the X-chromosome varies from 1:30 to 1:53 depending on the temperature, and if mutations occur in other chromosomes at the same rate as in the X-chromosome, a new lethal mutation in one or another chromosome occurs in about 1 fly out of 13. They further argue that since a sex-linked lethal mutation appears in about one fly in fifty and since there are two X-chromosomes in the female such a mutation would occur in one X-chromosome in about 100 *generations* and, since there are about 25 generations a year, say once in 4 years. It seems probable that there is some confusion in this reasoning since if a mutation occurs in one X-chromosome in every 100 *X-chromosomes* it should appear much more frequently than once in every 100 *generations.*

If mutations are proportional to the number of genes they should be much more numerous in very complex organisms than in relatively simple ones. It is not evident that this is the case. It is true that most mutations are positively injurious, or at least that they are less beneficial than the typical characters of wild species, and therefore they are eliminated almost as soon as they appear. Consequently such mutations are rarely seen unless they are searched for diligently. In all probability mutations are more numerous and occur more frequently than is now known, but the evidence seems to favor the view that they are more numerous in some species and phyla than in others. Whether they are caused by environmental conditions and are therefore proportional in number to environmental changes is at present unknown, although Muller and Altenburg indicate that they occur more frequently at high temperatures than at lower ones.

4. *Species* are presumably the result of the heaping up of viable mutations. The term "species" is an indefinite one and is not everywhere used in precisely the same sense. Nevertheless a very casual survey of the living world shows that some groups of animals and plants have undergone very much more extensive diversification than other groups. If we consider merely the approximate number of known spceies both living and extinct in different phyla of the animal kingdom we find very great differences as is shown by the following table of the approximate number of species in the principal animal phyla:[1]

Protozoa	8,000
Sponges	2,500
Cœlenterata	4,500
Platyhelminthes	5,000
Nemathelminthes	1,500
Rotifera	500
Polyzoa	1,700
Annelida	4,000
Arthropoda	400,000
Mollusca	61,000
Echinodermata	4,000
Chordata	36,000

In the different classes of Arthropods there are:

Crustacea	16,000
Arachnida	16,000
Myriopoda	2,000
Insects	360,000

In the different classes of Vertebrata the number of known species is about as follows:

[1] See Pratt, H. S., "On the Number of Known Species of Animals," *Science*, N. S., Vol. 35, 1912.

Pisces	13,000
Amphibia	1,400
Reptilia	3,500
Aves	13,000
Mammalia	3,500

These numbers represent merely a crude approximation of the number of known species, both living and extinct. Undoubtedly many more species remain to be discovered and this number will be larger among the Protozoa, for example, than among the Chordata and in the Pisces than in the Mammalia. For our purpose however this crude census of the number of species in different phyla of the animal kingdom and in different classes of the arthropoda and the vertebrata will suffice.

(*a*) It is at once apparent that the number of species in a group is not dependent entirely upon its age. Birds which arose in the Jurassic and are the most recent of vertebrate classes have more than 3 times as many species as mammals which first appeared in the Triassic and are therefore older. There are 100 times as many species of arthropods as of echinoderms though apparently both phyla are of about the same geological antiquity; there are 15 times as many species of mollusks as of annelids and more than 4 times as many species of chordates as of protozoa, although the former represents the most recent and the latter the most ancient phylum of the animal kingdom.

(*b*) Furthermore the number of species is not wholly dependent upon the number of individuals produced nor upon their rate of reproduction, as might be inferred from some of the recent discussions of mutation and natural selection. Protozoa and protophyta probably include vastly more individuals than all other groups of organisms put together and their rate of multiplication is many times greater than in any other group and yet the number of recognized species is relatively small. Chordata are probably poorer in individuals and their rate of reproduction is much slower than echinoderms though they are 9 times as numerous in species. Birds which are relatively few in number of individuals and of eggs produced have as many species as the much older class of fishes which lay perhaps a thousand times as many eggs. If evolution depends upon the chance production of mutations and the sorting of these by natural selection it might be supposed that mutations would be most abundant where fecundity was highest and that fish or starfish or oysters which produce approximately a million eggs a year would evolve much more rapidly than birds which lay only from two to twenty eggs a year: that frogs which lay possibly 200 eggs a year would evolve more rapidly than mammals which produce only from one to twenty young per year. Even within the same class and family there is no direct correlation between the number of young produced and the number of species, as is shown by a comparison of passerine and gallinaceous birds; in the former group the number of eggs laid is small but there are 5,700 living species, while in the latter where the number of eggs is perhaps from 5 to 10 times as great, there are only 400 living species. In the genus *Crepidula*, a prosobranch gastropod, there are 60 times as many eggs produced by an individual of the species *fornicata* as by one of *convexa* yet individuals and mutations are apparently no more numerous in one species than in the other. In general it seems that *evolution has been more rapid where fewer young are produced and these are better cared for.*

In none of these cases is the smaller number of eggs or of young produced compensated for by a larger number of individuals which are reproducing. To a certain extent the number of individuals in a species is correlated with their size; the smallest of all animals, the protozoa, are the most numerous in individuals, the largest, elephants and whales, are the poorest in individuals, but in comparing the number of species in a group there is no constant correlation between size of individual and rate of reproduction, though in general the smaller animals reproduce more rapidly than the larger ones. On the other hand there is no satisfactory evidence that smaller animals undergo more rapid evolution than larger ones.

(*c*) The rate of evolution is not always dependent upon changes in environment and diversities of habitat. There are more species of marine organisms in the tropics, where the environment is relatively uniform than in temperate regions. Amphibia which inhabit both land and water have only one-tenth as many species as fish which inhabit water alone, and echinoderm species are nearly twice as numerous as sponges, though both are confined entirely or almost entirely to the sea. Undoubtedly, however, there are more chances for the survival of mutations among living things which are able to adapt themselves to many kinds of environment than among those which are confined to a limited medium or habitat. Thus the fact that arthropods are by all odds the most richly diversified phylum in the animal kingdom is probably associated with the fact that they have extended into all media, namely, sea, fresh water, land and air. The echinoderms on the other hand have been confined entirely to the sea probably owing to the fact that because of inherited constitution they were unable to adapt themselves to other media; accordingly the number of species of echinoderms is much less than that of arthropods. Many paleontologists maintain that the rate and direction of evolution are determined by environmental changes and they describe "waves of evolution" as caused by intermittent changes of environment.

(*d*) If the chances of mutation were equal in all classes of organisms and if mutations represent chance alterations in the structure of the germplasm the number of mutations which appear would be dependent merely upon the number of young produced; but the number of these mutations which survive and give rise to species is undoubtedly limited by the environment, that is by natural selection. Mutations generally are wiped out almost as soon as they appear because they render the organism less viable or because they are not capable of further development, owing either to physico-chemical limitations of the germplasm or to environmental limitations. If this be granted the question still remains *why* are mutations more viable and more promising in some groups than in others?

No satisfactory answer can be given to this question at present but it seems probable that the rate of mutation depends primarily upon the particular organization of the germplasm in different groups of animals and plants. Some types of germplasm may be relatively stable and mutations few in such cases; other types relatively unstable and here mutations may be more numerous. Whether mutations will lead to the formation of species or not will depend in part upon the character and number of the mutations, and in part upon the environment, for the persistence of a mutation must depend upon its finding a suitable place in nature.

II. Adaptation

All kinds of organisms must be fairly well adapted to their conditions of life if they are to survive. The very fact of survival is evidence of adaptation. There is no evidence that protozoa are not as well adapted to their conditions as fishes and birds and mammals are to theirs. We cannot therefore assume that adaptations are less complete in lower forms than in higher ones, but they are certainly less complex and perfect as will be at once apparent when one compares the eye of a jelly fish and that of a fish or bird or man. We have here the same problem that we meet in individual development; germ cells, developing eggs and embryos must be adapted to their conditions of life if they are to survive, but those conditions and the corresponding adaptations are not so complex as they are in fully developed animals. This increasing complexity and perfection of adaptation from the lowest to the highest forms is part of the problem of progressive evolution and will be considered in the next section.

If adaptations are the result of chance mutations and the elimination of the unfit the rate of adaptation should be proportional to the number of such mutations and the severity of elimination; other things being equal, the number of mutations and the severity of elimination should be proportional to the rate of reproduction; consequently the rate of adaptation should be proportional to the rate of reproduction. There is no evidence that this is true, and when we consider the complexity and perfection of adaptations in higher forms it seems that the reverse is true and that adaptations have gone farther and faster in organisms in which the rate of reproduction and of elimination is relatively low.

III. Progressive Evolution

Thousands of species appear which do not lead to any increase in differentiation or in complexity of organization; they appear and if they find a suitable place in the world they may persist, but most of them do not represent any real progress. Almost all of the mutations which have been studied hitherto are retrogressive in that they represent a simplification of germplasm if not of adult structure and while some of them represent stages in the formation of species few, if any of them, represent a real increase in differentiation. Indeed progressive evolution, as distinct from speciation or adaptation, has apparently halted in almost every group of organisms; usually neither mutations nor real Linnean species lead anywhere except to mere diversity. There are probably more than a million known species of animals and plants both living and extinct and yet there have been relatively few lines of progress.

Whether evolution will lead to increasing complexity of organization or merely to diversification must also depend upon the nature of the germplasm; increasing complexity in evolutionary series must have depended upon rare and fortunate mutations which were not only viable but contained the possibilities of much further evolution and which were peculiarly suited to a favorable place in nature. On the other hand every mutant or species does not represent the beginnings of a new path of evolution probably because it is limited by the constitution of its germplasm so that further progress is rarely possible. The old explanation of the cessation of progressive evolution among protozoa, for instance, was a purely teleological one, namely, they remained protozoa in order that they might occupy a place in nature which would otherwise be unoccupied. The true explanation is more probably that they are incapable of further progressive evolution; they have branched off from the main stem of progress and can not now return. The case is like that of the differentiation of cells in development; the only cells which remain capable of indefinite development are the germ cells; muscle cells and nerve cells can not again become germ cells, and in a similar way the only cells which remain capable of progressive evolution are certain kinds of germ cells in certain groups of organisms. Certain species, like certain cells, have become so highly differentiated in particular lines that they cannot progress much beyond the limits already reached; they are too highly specialized to give origin to new lines of progress.

Paths of Progress

In general progressive evolution implies an increase in the differentiation and integration of parts. In unicellular organisms such increase of organization is seen in the multiplication and differentiation of many minor parts of the cell such as chromomeres, chromosomes, nuclei and the various units and organellae of the cytoplasm. The utmost limits of such progressive organization within the limits of a single cell were reached relatively early in the history of life upon the earth. Living protozoa and protophyta are probably no more complex than those which existed in the Proterozoic Era and certainly there is no reason to suppose that unicellular forms are now undergoing progressive evolution; they ceased long ago to advance in organization and since then they have changed only in the direction of diversification or speciation.

1. *Multicellularity.*—A new path of progress was found when unicellular forms gave rise to multicellular ones. When the protozoan ancestors of the metazoa divided, the daughter cells no longer moved apart, and at the same time these daughter cells retained the differentiations which they had at the time of division and in the course of further evolution added to these differentiations. In this way individual cells and cell aggregates became new units of differentiation and the entire organism, composed of multitudes of such cells, was able to reach a stage of organization which was entirely impossible within a single cell.

A similar transition from a unicellular to a multicellular condition is seen at the present day in the development of an egg. The single egg cell shows certain differentiations, as does also the sperm cell, but these differentiations never go farther than the type of differentiations characteristic of a protozoan. By repeated divisions of the egg, cells are formed which adhere together and the initial differences which these cells have at the time of division are maintained and augmented as the cleavage of the egg proceeds—that is, there is no regulation following division by which each cell replaces lost parts and becomes like the original egg cell as happens in the division of a protozoan. However if the cells fail to remain united they do undergo a certain amount of regulation returning more or less to the condition of the egg; and if cell division is stopped differentiations quickly come to an end. In short it is necessary that the egg shall divide into many cells and that these cells shall remain in contact in order that differentiation may proceed; cell division is necessary to embryonic differentiation and cell union to organic integration. Multicellularity is thus one of the most important paths of progress that organisms have ever discovered.

2. *Multiplicity of Tissues, Organs and Parts.*—As multicellularity led to the possibility of differentiations between individual cells, so the grouping of similar cells together with their products into tissues, of tissues into organs, and of organs into systems has enormously increased the possibilities of differentiations among these parts. Within one of the higher animals or plants there are therefore many units of structure of varying degrees of complexity and among these there are innumerable numbers of differentiations while at the same time all are integrated into a single organism or person.

3. *Compound Organisms.*—Finally combinations of organisms known as corms, due to incomplete division, are found very generally in the plant kingdom and among the lowest animals such as sponges, hydrozoa, and polyzoa. Evidences of such incomplete division are found also in the segmentation of tapeworms, and in the metamerism of annelids, arthropods and vertebrates. In many of these cases this incomplete division makes possible a differentiation of the various zooids or segments so that as in the case of the hydrozoa one zooid may be nutritive in function and structure, another reproductive, another protective, etc. In metameric animals there may be a notable differentiation of different metameres; indeed in all the higher animals metameric differentiation is one of the

chief methods of bringing about increasing complexity of organization. Thus by the multiplication of cells, tissues, organs, systems, and zooids or metameres; by differentiations among the members of each of these classes; and by the integration of all of these into a single individual a degree of complexity of organization, both as to structure and function, is reached which so far as is known has no parallel elsewhere.

Just as some of the most complex protozoa represent the highest possible organization within the limits of a single cell so some of the most complex multicellular animals and plants represent the highest possible degree of organization within the limits of a single body. But no single animal or plant, however complex it may be, can combine within itself all the complexities of all organisms. The very nature of differentiation signifies limitations in certain directions in order to secure further development in other directions. If a vertebrate have wings it cannot also have hands (except in the artistic representation of angels) ; if it have limbs differentiated for running, it can not also have limbs specialized for swimming; if it have enormous strength it can not also have great delicacy of movement. Thus while certain animals are differentiated in one direction and others in another no one animal can be differentiated in all directions.

There is good reason to believe that multicellular organisms have already reached and in many cases passed the highest stage of organization which is possible within the limits of a single body. When differentiations in any one direction go so far that they unfit the organism for any condition of life except a single and special one the chances for survival are greatly reduced and sooner or later this highly differentiated organism becomes extinct or returns to a more generalized condition. Such limits to progressive differentiation have been reached in practically every group of animals and plants. The climax of the progressive evolution of fishes was reached in the Paleozoic Era, of amphibians in the Permian, of reptiles in the Mesozoic and of mammals in the Tertiary. In all these classes the formation of new species and genera has been going on throughout their entire history, there has been diversification and speciation without cessation, but progressive evolution in the sense of increasing complexity of organization has reached its limit.

In all existing classes of animals and plants progressive evolution has practically ended. Even in man, one of the latest products of evolution, there is evidence that physical and intellectual development have gone about as far as is possible; there is not much prospect that the hand, the eye or the brain of man will ever be much more perfect than they are in many persons at present. It is of course conceivable that further evolution of the brain for example may occur, just as it is possible to conceive of a further evolution of the neck of the giraffe or of the trunk of the elephant, but there is a practical limit beyond which it is not possible to go. Differentiations must not go farther or faster than integrations and they must not render their possessor less fit to survive. It is very doubtful whether the brain of man could undergo much further differentiation without introducing disharmonies within the organism or with the environment.

Both in complexity of organization and in perfection of adaptation progress has always been most rapid at first and has then gone slower and slower until it stopped. It may be compared to a curve which rises rapidly at first and then approaches more and more to a straight line. Or better still it may be compared to a flow of lava which rushes forward while it is at a white heat and fresh out of the crater but goes more and more slowly as it cools until it stops altogether; if the central stream remains fluid (or the organism remains labile and relatively undifferentiated) it may burst out and again flow rapidly in one direction or another until it again cools and stops. Probably the farthest possible limits of progressive evolution have already been reached in all well-tried lines of progress. Further progress must be made in new lines if at all.

Among animals no new phyla have appeared since the vertebrates in the Silurian or perhaps even earlier; no new classes since the mammals in the Triassic and the birds in the Jurassic. In the evolution of animals only about fourteen times in the whole history of life have new phyletic paths been found and several of these were practically blind alleys and led nowhere, not even to the production of many species, as, for example, the ctenophores, the rotifers and the chætognaths. Apparently, therefore, the progressive evolution of multicellular organisms has come to an end so far as increasing complexity of organization of individuals is concerned.

4. *Social Evolution.*—Just as a great advance was entered upon when the path of multicellularity was taken, so a still greater advance was made possible when solitary forms entered upon the path of social organization. There are many grades of individuality in the living world from the visible and even the invisible parts of cells to whole cells, cell-aggregates, tissues, organs, systems, persons, corms, and finally colonies

and states. There are many grades of organization from the bacterium to the vertebrate, from the germ cell to the man. Animal societies are the last and highest grade of organization which has yet appeared on earth. In such societies the integration and cooperation of individuals makes possible a higher degree of differentiation than has ever appeared before, and the degree of differentiation of individuals which is possible is directly proportional to the extent of their integration.

The evolution of animal societies may be traced from a condition in which every member is much like every other and the bond of connection between individuals is a very loose one, up to societies of ants, bees and termites in which the specialization of individuals is higher, the mutual dependence more complete, and the work which the colony is able to perform is immensely greater and more perfect than could be accomplished by any number of individuals working separately. What the individual cannot do because of weakness, lack of differentiation and short life, the social group can accomplish with the strength and specialization of all and through long periods of time.

Whether social evolution, in which instincts alone are the integrating factors, has reached its highest possible development in colonies of ants, bees and termites no one can say, but it is certain that any further evolution along this line must lead to greater differentiation and integration of the constituent individuals, or of entire colonies.

5. *Rational Evolution of Human Society.*—Finally with the development of intelligence man has entered upon a new path of evolution in which progress has been extraordinarily rapid, namely the path of rational cooperation. All animal societies are based upon gregarious instincts and these instincts form the only bond of integration in most of these societies, but in man they are supplemented by intelligence and upon these gregarious instincts as a foundation rational cooperation has erected that enormous structure which we call civilization.

It is a notable fact that the social evolution of man has been very much more rapid than his physical evolution. In physical organization man has changed but little since the beginning of recorded history but in social organization the most enormous advances have been made and changes are still going on at a rate which is amazing if not alarming. The chief reason for this difference in the rate of physical and social evolution is to be found in the fact that experiences are more quickly registered in the intellect than in bodily structure or even in the instincts, and that in intelligent social groups all past experiences may be transmitted to future generations, so that each new generation stands as it were on the shoulders of the preceding ones. On the other hand so far as bodily structures, functions and instincts are concerned, each generation begins life anew as germ cells and if it inherits any characters due to the experiences of its ancestors they are few and rare.

Conclusion

Finally if the rate of *divergent evolution* depends upon the number of mutations which appear, it should be proportional, other things being equal, to the rate of reproduction. But this as we have seen is not the case. If the rate of *adaptative evolution* depends upon the rate of mutation and the severity of elimination it also should be proportional to the rate of reproduction. On the other hand, some of the most highly adapted forms such as birds and mammals have a relatively low rate of reproduction. If all members of a phylum have evolved from a common ancestor those which have gone farthest in any line of adaptation must have gone fastest; but in general the most highly adapted forms have a low rate of reproduction. If the rate of *progressive evolution* depends upon the rate of mutation and the severity of selection it also should be proportional to the rate of reproduction, but it is at once apparent that this is not the case; the most complex and most highly differentiated of all animals have the lowest rate of reproduction.

These considerations lead one to seriously inquire whether recent theories as to the causes of evolution are wholly satisfactory. The rapid rate of evolution in active and highly complex but slow-breeding animals would be readily explained on Lamarckian principles. It seems highly probable that the rate of mutation is influenced by environmental conditions, as Plough has shown in the case of the pomice fly, and it is probable that environment has played a large part in the rate of evolution. On the other hand, the evidences against the inheritance of the effects of use or disuse are so strong that one hesitates to invoke their aid. Nevertheless a broad view of the past evolution of life upon the earth, of evolutionary diversity, adaptation and progress, and especially considerations of the rate of evolution, cause one to inquire whether there may not be other important factors which possibly are not yet "dreamed of in our philosophy."

POPULATION[1]

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THERE is scarcely a subject in whose depths one may escape the problem of population. It pervades history and sociology, it penetrates ethics and philosophy, it influences science and the arts. This is because it is solely in man's own interest, his food and protection, his love and happiness, that he founds social and political systems, establishes codes of morals, and otherwise busies himself going to and fro upon the earth. If there be an unvoiced criticism that these are mere platitudes founded on man's domination of the world, and that a diversity of phases in the problem of population, as usually delimited, does not necessarily follow, it is not well-founded. The *problem* of population takes form when it is realized what a large number of these vital interests of mankind are antagonistic to each other, are even mutually exclusive. And as a problem not one of these numerous ramifications may profitably be excluded.

In spite of the catholicity of the subject, it has had definite consideration by only two classes of thinkers, theologians and economists. The theologians have discussed it with their habitual effusiveness, but their examination has been superficial. For them, mundane happiness has a very low order of magnitude. It is a distasteful matter, unworthy of the spiritually minded. Such progress as has been made, and it should not be minimized, has resulted from the analysis of the economists. And I say this mindful that the man who made the greatest original contribution to the subject was entitled to place the word Reverend before his name; for he wrote as an economist, not as a theologist.

I submit, however, that there should be no such monopoly. Such a momentous and difficult problem should not be the sole property either of priest or politician, of economist or social worker. I do not suggest its preemption by the biologist; yet by its nature the question is fundamentally biological, and if the biologists do not interest themselves in it, it can not receive the attention it deserves.

[1] Address of the retiring President, delivered at the thirty-seventh annual meeting of The American Society of Naturalists held at Princeton, New Jersey, December 30, 1919.

The problem of population is not new. Like all general questions it has interested mankind ever since there has been some modicum of civilization. But, with that scholasticism characteristic of the majority of publicists of all times, it seldom has seemed necessary to base their statements, theories, or laws, upon concrete facts. One obtains little reward other than cynical amusement in following out its history, from the *Lex Papia et Poppœa*,[2] enacted for the purpose of encouraging marriage and legitimate fecundity, by the efforts of two old bachelor consuls in the year 10 A.D., to the analogous contemporary propaganda of our erstwhile bachelor colleague Popenoe,[3] from the naïve teachings of the early Christian fathers, to the modern headline that "Mrs. Blindly Helpful warns of birth decline,"—probably in the same awed tone that Little Orphan Annie whispered, "the goblins 'ill git you." But even as the development of the doctrine of evolution is comparatively uninteresting until one reaches Lamarck and Darwin, the theories of population have little intellectual standing until the time of Franklin[4] (1751) and Malthus[5] (1798).

Franklin's chief contribution to the subject was a short essay entitled "Observations concerning the Increase of Mankind and the Peopling of Countries." In it the dependence of population increase or decrease on food, commerce, type of government and conditions of labor, were succinctly and accurately stated. Malthus acknowledged his indebtedness to Franklin; but the fate of Franklin's essay as compared to Malthus's treatise was as those of Wallace and of Darwin on Natural Selection, the logic was good but the basis of material fact was small.

Malthus, on the other hand, delved successfully for facts and found their meaning. In spite of bitter criticism his work is accepted to-day by leading economists with little change. The only difficulty is that the world is inclined to blunder along without heeding Malthus's warning. It sits gaily at its present feast oblivious of the *mene tekel* on the wall. How many of our leading biologists, even, have read the "Essay on Population"? They know it gave to Darwin his long-sought concrete cause of organic evolution, Natural Selection, but in general can they

[2] Strangeland, C. E., "Premalthusian Doctrines of Population," Studies in History, Economics and Public Law, Vol. 21, No. 3, pp. 1–356, 1904.

[3] Popenoe, P. and Johnson, R. H., "Applied Eugenics," New York, Macmillan, 1918, pp. 459.

[4] Franklin, B., Miscellany. (1751.)

[5] Malthus, J. R., "An Essay on Population," 3 vol. Georgetown, Milligan, 1809. First American from third London edition.

do more than speak vaguely of a geometrically increasing population pressing upon an arithmetically increasing food supply? If the scholar thus casually passes by a fundamental cause of past, present and future social unrest, can one justly call to court the harebrained Bolshevist for his fallacious doctrines, or rail against legislators, who, true to their primary principle of holding firmly to their jobs, pass resolutions to investigate the high cost of living or the relations of labor and capital, with the same aplomb as they would undertake to investigate the law of gravitation could such a procedure further their political fortunes?

Malthus's work went through many editions. In some particulars the first imprint was more pessimistic than the later revisions. Perhaps if the author were alive to-day he would return to his first impressions; but since the purpose of this paper is to look into the facts as they affect the present and the immediate future, I shall epitomize his mature conclusions as given in the third edition.

The object of his inquiry was to examine the causes impeding the happiness of mankind, and to speculate on the probability of their removal. The chief cause of distress and misery he attributed to the constant tendency of man, in common with the lower animals, to increase beyond the means of subsistence. Irrational animals, he states, are powerfully impelled to increase their species freely, deterred by no doubts about providing for their offspring; and the results of this freedom are afterwards repressed by want of room and nourishment. Mankind, impelled to increase by the same instinct, is somewhat checked by reason; but nevertheless the tendency is such that the increase of mankind actually does press upon the means of subsistence to such an extent that various forms of misery, or the fear of misery, are the direct result.

The ultimate check to population is thus a want of food which necessarily results from the different ratios according to which population and food increase.

> The immediate check may be stated to consist of all those customs, and all those diseases, which seem to be generated by a scarcity of the means of subsistence; and all those causes, independent of this scarcity, whether of a moral or physical nature, which tend prematurely to weaken and destroy the human frame.

These obstacles to increase, he maintained, were resolvable into moral restraint,—to which one may to-day add artificial family limitation,—vice, and misery. To state the matter a little differently, increase in population is the chief cause of misery in so far as that misery is caused by the struggle for existence. Under this head he named "unwholesome occupations, severe labor, extreme poverty, undernourishment of children, great towns, excesses of all kinds, the whole train of common diseases, wars, plagues and famine."

One may without exaggeration add materially to this list, for all of man's activities are resolvable into a struggle for existence and a struggle for perpetuation, and it is the antagonism of these two instincts that leads to all the trouble.

To my mind, the Reverend Doctor proved his case very neatly in the three volumes of his work. Not only that, but he discovered two principles as corollaries to this main thesis, which are particularly important at the present day. The first is to the effect that emigration relieves population but temporarily, owing to the increased birth rate of the remaining population resulting from a release of the economic pressure. The second is that the lower classes of a population tend to replace the upper classes,—a natural conclusion following from the fact that that part of the population which takes no thought of the future has the highest birth rate.

Nevertheless, in spite of this thorough and scholarly attempt to place before the public logical conclusions on this great problem, induced from concrete facts, in spite of later analysis and acceptance by every economist of note, there is still a hue and cry for population. European countries, crowded to the utmost, appoint commissions to inquire into their declining birth rate, and to take steps to increase it. Tempestuous people in the public eye thunder forth *dicta* about the subject, though blindly ignorant of the facts and making no pretense of learning them. Even those who pass for scientists and might be expected to look into the subject, seem obsessed with the same idea. Witness a paper[6] delivered a short time ago by the statistician of the Metropolitan Life Insurance Company at a meeting of the American Association for Advancement of Science, and afterwards spread broadcast as a part of *The Congressional Record.* It is difficult to account for such narrowness of view, superficiality of logic, and general inability to grasp the broad problem, as is exhibited in this paper. If these are the reactions of those from whom some basis of knowledge might reasonably be demanded, what is to be expected from the man on the street who is entranced as with a toy by the mere idea of bigness—a

[6] Dublin, L. I., "The Significance of the Declining Birth Rate," *Science*, N. S., 47: 201–210, 1918. See also reply with same title by Ellen Hayes, *Science*, N. S., 50: 533–536, 1919.

big country, lots of people—let them live as best they may. But enough of this; let us examine the facts on the subject as we face them to-day.

In the time of Malthus, the world could still be considered as a collection of more or less isolated geographical entities. Succeeding the original development of subraces through real isolation, there had been waves of migration with resulting intermixtures of peoples, it is true; but at that time, a short 100 years ago, there remained a condition of geographical separation which has now been swept away. The world war brought home to us the illusiveness of distance. In considering the question before us from the broadest point of view, the whole globe must be treated as a unit.

How fast the population of the earth has increased in the past is an unknown quantity, and will remain unknown. An estimate of the present population or of its natural increase is not accurate by any means, but is more than a random conjecture. From the returns of the Registrar General of England, the Census reports of the various civilized countries, the Statemen's Year Book, and the opinions of several travellers in Africa and the Orient, I estimate that there are at present 1,700 million people. A careful review of the factors involved leads me to believe that the probable error is not greater than $\pm$ 40 million. Again, the annual natural increase estimated country by country, disregarding the effect of the war, totals not less than 14 million or more than 16 million. This is an average rate of about 9 per thousand. To show that this estimate is conservative, I may say that a letter from the Office of the United States Census rates the annual increase of population in the world at approximately 25 million.

Consider a moment what these figures mean. Not long ago we were asked to speed production, to save, to waste nothing, that Belgium might be fed and clothed. We did this and more, and we may well be proud of a difficult task efficiently accomplished. But, have we realized, can we realize, that 2 Belgiums are added to the world's population each year? And all must be fed,—though perhaps some need not be clothed.

Segregating this increase by races as accurately as one may, shows that the white race is increasing much more rapidly than either the yellow or the black. China's 300 million population is practically stationary; India and the South Sea Islands are increasing spasmodically, but probably not at a greater rate than 8 per thousand. Japan, on the other hand, has a natural increase of over 13 per thousand; and the theoretical curve fitted to the crude birth rate is *rising*, though the crude death rate is stationary. The blacks are increasing rapidly only in this country, where the natural increase is now about 11 per thousand, and in the West Indies. In Africa they are increasing but slowly. In some parts they are actually decreasing, and it is doubtful if they reach the figure for the United States even in the richest sections of the continent. The white race is the race on the road to numerical domination. With the exception of France, few white peoples are increasing at a less rate than 10 per thousand. The countries of eastern Europe, Russia, Rumania, Bulgaria and Serbia, with tremendous birth rates, from 40 to 50 per thousand, are increasing at a rate of from 17 to 19 per thousand, while Australia and New Zealand, with low birth rates, from 26 to 28 per thousand, are multiplying at nearly the same speed, due to their low death rates.

It is natural to ask how the Great War affected these estimates. No precise answer to the question can be given, because it is just possible that the after effects of this war will be unlike the after effects of previous wars, in that the birth rate will continue to be depressed below the pre-war figures. Personally, I do not believe this will be the case. I believe we may read the future in the past, and that the birth rates will take such upward trends in the war stricken countries that in a very few years they will readily fit projections of the pre-war curves. In other words, I believe it to be a fair prediction that so far as general gross natural increase of population is concerned, the curve when plotted from 1900 to 1950, if that be some day possible, will show only a temporary deflection for the years 1914 to 1919. The tide of population is not kept back by the flimsy barrier of war, it is but baffled for the moment.

Naturally, if one looks at the subject more minutely, he cannot deny the great influence of the war upon the countries primarily involved. The reports are conflicting, but various official estimates place the direct losses at between 10 and 12 million. The indirect losses are hardly more than half as much, —perhaps much less. Indeed if one could correct for lessened death rates due to army training, the total would be materially diminished. It may be doubted, therefore, whether all losses, direct and indirect, attributable to the war, are over 18 million. And I may say that this statement is not made haphazard, but after due consideration of the data from the statistical divisions of several of our own and other governmental agencies. Compare this, then, with the effects of the pandemic of influenza in which not less than 20 million people are thought to have lost their lives. Numerically, both of these figures are terrible, staggering, incomprehensible; yet on a percentage basis they are trifling when compared with the wars and plagues which swept Europe and Asia in former times, and from which they recovered with astonishing rapidity.

Let us turn for a moment to the potential loss due to the decrease in the birth rate. An estimate in 1917,[7] based on cities in Germany comprising about one sixth of the population, showed that the German birth rate had dropped about 10 per thousand. If we assume this to be correct for warring Europe plus Turkey in Asia, three years potential loss is approximately 8,500,000.[8] This figure allows Russia in Europe but one third the loss of the others, for the very good reason that the Russian manner of living is such that a loss of 3 or 4 per thousand more nearly represents the facts, and excludes the United Kingdom where the depression was slight. This again is a great potential loss, but is it not small compared with the total population of the countries involved, and will it not be made up as it has at the close of all other wars by a temporary supernormal birth rate? Furthermore, in central Europe it was found that the war conditions actually made for a lower infant mortality, probably because of a greater frequency of enforced breast feeding; and the actuality of the potential loss is not wholly what it seems to be.

These facts are given for the purpose of showing that in spite of wars, notwithstanding plagues and pestilences, the world goes merrily on obeying to the letter the biblical injunction, "increase and multiply." But I hear the question, is this going to continue? Is there not a generally decreasing birth rate? Yes, this is true. In most of the civilized countries of the world the birth rate is slowly but steadily decreasing. The result, however, is not what many would have us believe. The inter-nation correlation between the birth rate and death rate is high. In general, where the birth rate is high, the death rate is likewise high.[9] Where the birth rate is low, the death rate is

[7] Vital Statistics in Germany. Taken from Veröffentl. d. k. Gsndhtsamtes (41: 1917), by War Office. Issued in Medical Supplement, Review of the Foreign Press.

[8] *Cf.* Mallet, Sir Bernard, "Vital Statistics as Affected by the War," *Jour. Roy. Stat. Soc.*, 81: 1–36, 1918.

[9] *Cf.* Drysdale, C. V., "The Small Family System," New York, Huebsch, 1917, pp. 196. Also "The Declining Birth Rate: its Causes and Effects." Rpt. National Birth Rate Commission (Great Britain). New York, Dutton, no date (preface dated 1916), pp. 450.

low. Australia, New Zealand and Holland with low birth rates have tremendous rates of natural increase, rates much higher than many other countries with very much larger birth rates. There is but one outstanding exception to this rule—France. Though France reduced her births, she failed to reduce her deaths as fast as might reasonably be expected in a country with her standard of culture. Having reached a point where there is practically no natural increase, therefore, her death rate more nearly measures the absolute length of life of her inhabitants, and for that reason seems abnormally high. Were the birth rate of France to take a sudden rise, there would be the apparent paradox of a fall in the death rate due to an increasing population. Nevertheless France stands alone in this. Other countries from which we have statistics are still increasing, and in them the positive correlation between the birth and death rate holds; although in saying this we make no claim as to the relation for intra-nation correlation on a time basis, for the simple reason that it has not been adequately studied. It is a fair prediction, however, to say that owing to the steadily increasing development of medicine and of general sanitation, the decrease in the birth rate will have no great effect on the natural increase in the world for many years to come. In fact it would not be surprising if during the next 50 or 100 years the excess of births over deaths should go up rather than down in many countries.

What is to become of this flood of people? The international situation at present is this. China is stationary in population, —a high birth rate (if we may believe reports), and a high death rate. With a permanent system of agriculture she feeds herself. Northern Asia, Central Asia and even India can support a few more people. Australia and New Zealand are increasing at a rate which their possibilities in the way of food production can stand for only a short time. Europe, as a whole, is already over-populated. England is in the least desirable condition, with the countries of northern Europe running her a close second. By great efforts Europe can support its present population without extreme hardship, but the efforts must be sustained and efficient. There remains then, Africa and South America, as colonization centers,—the United States we leave for separate consideration. These places should be able to support a large number of people. True, large portions are tropical, and the white man has not been a particularly successful occupant of the tropics; nevertheless one may predict, without undue optimism, that these difficulties will be conquered, and that these lands will repeat the history of North America. There will be emigration from Europe, and perhaps from Asia; there will be a birth release in the new lands; and they will teem with people. And let us make no mistake here. If science makes this development possible, the time when Africa and South America are filled to the practical limits of their food production is no dim and distant future. If the rate of increase actually existent during the nineteenth century in the United States should obtain, within the span of life of the grandchildren of persons now living, these countries will contain over a billion inhabitants.

Long before this eventuality, the struggle for existence in those portions of the world at present more densely populated will be something beyond the imagination of those of us who have lived in a time of plenty. Each geographical unit must then of necessity produce its food. It will be impossible for a country to maintain a position such as that of England. Excess population supported by commerce will be a thing of the past. There will be commerce, of course, but exportation of food in quantity will not longer be tolerated.

To present this matter in a way which will bring home the economic and biological consequences of population pressure. let us consider it in some detail as it affects the United States. We have taken the census thirteen times,[10] 120 years,—not a long period as even history is measured. In 1790 the population was 4 million; in 1910 it was 92 million. In 1920 we may expect to have somewhere near 110 million people. In 120 years, the country had increased in population 23 times; in 130 years, it presumably will have increased 27 times. More minutely, of the 92 million returned by the enumerators in 1910, 82 million were white and 10 million yellow and black,—chiefly the latter. But of the 82 million white, only 68 million were native white, over 13 million being foreign born. If we look a little closer, we find that only about 49 million were native whites of native parentage,—32 million being either foreign born or of foreign or mixed parentage. Thus in 1910 only 53.8 per cent. of the population were native whites whose parents had been born in this country, though from 1820 the total immigration had been less than 28 million.

With this chronicle of the past as a basis, one may visualize the future, provided the causes of increase remain the same.

[10] All U. S. population figures from publications of the U. S. Bureau Census. Quoted figures on other countries from Reports of the Registrar General of England.

In 1891 Pritchett[11] found that the population curve of the United States could be represented by a parabola with the equation $P = A + Bt + Ct^2 + Dt^3 + \cdots$, where P represents the population and t the time from an assumed epoch. How well the projection of this curve has fitted for a short period is shown by the actual and the computed figures for the last three census years. In 1890 they were almost identical; in 1900 there was an excess of nearly a million and a half, and in 1910 an excess of over two million and a half in favor of the computation.

This is a rather good fit, all things considered; but, the fact that the actual population is already lagging behind the predicted population shows that the causes operating in the earlier history of the country have now been modified. The computations of 386 million for the year 2000 and 1,113 million for the year 2100, therefore, are much too high. Nevertheless, these are short periods, 80 and 180 years, respectively, and the tendency toward an almost unbelievable increase is strikingly shown. Let us keep in mind the *possibility* of taking care of 300 million people before all of our children have ceased their struggle for existence, and of supporting some 700 million who will compete with our grandchildren, while we turn our attention to the resources of the country as they exist to-day.

I know I shall be termed a preacher of calamities, but the facts admit of but one conclusion: the law of diminishing returns is even now in operation in this comparatively new country thought to be supplied with inexhaustible riches. This is the result of my own somewhat extensive investigation. It is the result of the accurate scholarly study of Thompson,[12]—the only economist, as far as I have been able to discover, who has had the courage to face the subject in a thoroughly scientific manner.

This age has been called the Age of Steel, an apt trade name for our present type of civilization. Nevertheless this period, like all ages past, and all times to come, is one of Agriculture. Civilization, like an army, marches on its stomach. The present and potential food supply is what interests us most. It is true we could show that in spite of the abundant supply of mineral wealth within our boundaries, all is not as well as might be.

[11] Pritchett, H. S., "A Formula for Predicting the Population of the United States," Amer. Stat. Assn. Quar. Pub., N. S. 14, Vol. 2: 278–286, 1891. This formula may not be the most precise one possible, but it serves our present purpose.

[12] Thompson, W. S., "Population: A Study in Malthusianism." Privately printed, Ann Arbor, 1915, pp. 216.

Our coal supply is being dissipated. Nearly a sixth[13] of our visible supply of anthracite has been mined within the limits of one generation. But 15,000 tons per capita of bituminous coal still remain untouched,—presumably enough for about 5 centuries with the present per capita consumption. Our petroleum reserve is speeding on its way at a still greater pace. Forty per cent. of the visible supply is gone, and merely at the present rate of consumption there is only enough left for some twenty-odd years.

If, as our mining experts claim, the total supply of these, our two main sources of energy, has been mapped properly, it would seem that our Steel Age is on the road to senility. To a Babylonian returned to look over the prospects, it would probably appear as a transient phase unworthy of particular notice. Perhaps matters are not so bad as they are painted, however. Our utilization of water power is still very limited, and in the more distant future we can look to the moon for our energy requirements. We shall harness the tides. In the case of agriculture, I am not so sanguine.

The sower, the tiller, the reaper, go their ways with the same changeless routine they have taken since the dawn of civilization. No fairy godmother has appeared to aid our most essential art; and the story of the past gives us reason to be skeptical of the future. In a way agriculture has become more efficient. Chemistry, physics and biology in their applied branches have given us a more definite knowledge of cause and effect, and have provided for a greater return per unit of man power. But he who makes two blades of grass grow where but one grew before must be prepared to pay the price in a lesser number of blades to come after. Novel methods of culture, more efficient machinery, new and better yielding varieties, are but means of exploiting a limited reserve of soil fertility at a higher rate.

It is curious what false ideas in regard to agricultural possibilities are held by so many people. Not long ago I asked a well-trained business man how much more land could be brought into cultivation. His off-hand estimate was between 400 and 600 per cent. Now the whole land area of the Untied States is only 1,903 million acres;[14] and 47 per cent. is now included in farms, although only about 55 per cent. of the area of these farms is improved. There remains 1,023 million acres, as a

[13] Gilbert, C. G. and Pogue, J. E., "The Energy Resources of the United States: a Field for Reconstruction," U. S. Nat. Mus. Bull., 102: 1–165, 1919.

[14] *Cf.* Thompson, W. S., *l. c.*

reserve supply. Of this, 468 million acres is arid land having an annual precipitation of less than 15 inches, 200 million acres must be preserved as forest lands, 75 million acres is swamp with perhaps 40 million acres permanently unusable, and 41 million acres is already in cities, roads and railroads. There is then a grand total of 749 million acres which must be withheld from agricultural use permanently, without allowing for urban and transportation increase. When this is subtracted, the 274 million acres left does not loom so large. There is a parcel of 40 million acres to be added, however, when all irrigation projects possible under the present system of construction are made available, making a total of 314 million acres. This calculation shows that we have been extravagant in our optimism. After the expenditure of vast sums, after the completion of tremendous tasks of engineering, we can add barely 35 per cent. to our present farm area.

We may catch at the straw in sight, and point out that only 55 per cent. of farm lands are improved, and that therefore when all available land is improved, 170 per cent. of our present area will be added. But this straw is loose, as a little consideration shows. The unimproved land of to-day remains uncultivated because the net returns for farm produce are not high enough to warrant its cultivation. Bluntly, it is too poor to be farmed until the price of food goes higher. Not only is this true, but it should also be emphasized that many farms in the older parts of our country, which once produced a profit, have so deteriorated after a lone century of cultivation that they are now either tilled at a loss or are abandoned.

It would be foolish to maintain that this country can not support a much larger population. This is not the economic question before us. The population will continue to increase for years to come, though more and more slowly as discomfort and want become more prevalent. My point is that the reserve farm land is less productive than the improved land, that the fertility of the soils now being tilled is decreasing, that the law of diminishing returns is now in active operation. If these are the facts, and the statements are amply supported, a continuous increase in the food cost of living must go hand-in-hand with an increase in population, although there may be a temporary after-war downward trend if production is sustained and the water forced out of our inflated currency. There will be more people, but there will be a more strenuous struggle for existence proportionate to the increase.

What is the reason for asserting that diminishing returns now show in agriculture? There are various ways of throwing light on the question, but data from two sources are sufficient. Elaborate chemical, physical and plot culture investigations of various soils[15] have been made by the Agricultural Experiment Stations of Illinois, Ohio, Pennsylvania and Minnesota, and less extensive experiments have been carried on in other states. One who takes the trouble to study the published reports of these researches with care is fully repaid. They prove beyond question that the farm soils of the United States are by no means of unlimited fertility. The three essential elements of fertility, so-called, potassium, phosphorus and nitrogen are present in such small quantities that the natural production curve of various types of soil under particular systems of cropping can be estimated with a fair degree of accuracy. And in most cases it is not centuries but decades before continuous cropping shows decreasing returns, no matter what the rotation.

Fortunately there is a comparatively large supply of potash in most soils, and there is nitrogen to be obtained from the air by the proper use of legumes or by electrical methods; but the phosphorus content, generally speaking, is so low that it soon becomes deficient if not replaced by artificial fertilizers, for nearly 4,000 million pounds of phosphoric acid[16] are removed annually by the grain crops alone,—nearly 20 pounds per acre. Fortunately again, the element commonly limiting the fertility of the soil may be supplied for a time from the large phosphate beds[17] of South Carolina, Florida, Tennessee and the Northwest, which contain over half of the world's supply, estimated by Hopkins at 500 million tons. The matter of prime importance, however, is not the *possibility* of keeping up crop returns for a considerable period when all available means are utilized. It is, that natural cropping by the present system is depleting all soils rapidly, and that millions of acres have already reached the point where their present productiveness can only be kept up by increasing amounts of artificial fertilizers. Much of our natural agricultural wealth has been used, with no charge made for it in the production costs. This is bad bookkeeping. No charge for depreciation means bankruptcy in any business.

[15] Hopkins, C. G., "Soil Fertility and Permanent Agriculture," Boston, Ginn, 1910, pp. 653.

[16] Hopkins, C. G., *l. c.*

[17] *Cf.* Wyatt, Francis, "The Phosphates of America." New York, Sci. Pub. Co., 1892, 4th ed., pp. 187.

Now that the fertilizer industry is increasing by leaps and bounds, and farming with the use of artificial manures must compete with new land farming, we can see more clearly what the ledger sheet of the future must show. Absolute costs per unit of man power, and per monetary unit, are mounting and will continue to mount, because of the diminishing returns which such a system entails. Furthermore, there will come a time, a time not so very distant, when the current agricultural system must be replaced. A more efficient system of saving plant nutrients similar to that of China and certain European countries must be installed. The elaborate scheme of waste evolved by our sanitary engineers will have to be discarded.

Perhaps there are those, however, who deny the truth of the current theories of soil fertility. Such denials have been made, though without the support of quantitative data. Nevertheless, be the theories of soil fertility what they may, the experiments on continuous cropping are facts. There is a decrease in *natural* productiveness with all known methods of continuous cropping, which is so rapid it may well alarm those who look toward the future.

Let us examine data on this subject from a second source. They are perhaps still more convincing. We see continually in the various reports of government agencies, how much the crops of the country for a definite year exceed those of a previous year or term of years in acreage, production, and value; yet it is of no particular importance that our production of crops or of food-animals is increasing. Paper wealth is cold comfort. What we wish to know is whether with improved machinery, new methods, and better varieties, our agriculture is keeping pace with our population.

The per cent. of actual increase in population in the decade 1900 to 1910 was 21. The per cent. of increase in farm lands during the same period was 4.8. But this does not necessarily mean a great deal. To obtain more pertinent data I have plotted the *per capita* production of meat animals, and of acreages and production of the chief agricultural crops from 1870 to 1916.[18] In order to obtain trustworthy figures, the enumerations of animals for the census years only have been used, while the production figures are the ten-year averages centering on the census years. The last point is the average for the years 1915, 1916 and 1917. The graphs are very interesting and

18 The figures upon which these calculations are based, have been taken from the Year books of the U. S. Dept. of Agriculture.

illuminating, but this is not the place to consider them in detail. The gross results are as follows. The peak of swine production, .951, was reached in 1880. In 1910 it was .633, and in 1916, .667. After various fluctuations sheep production reached .809 in 1900, but in 1916 was only .480. Milch cows have remained rather more constant, but the curve shows a downward trend since 1890. Other beef cattle, perhaps the chief meat supply, have dropped markedly from a high point of .666 in 1900 to .399 in 1916.

The vast grazing lands of the early days are gone and with them low priced meat has passed. Does one need any other reason for the rise in meat price-rates up to the year 1915?

Let us pass now to the per capita acreage of the great cereals and potatoes. Corn remained the same from 1880 to 1890, about 1.16, and has dropped slowly ever since. Wheat reached a peak of .67 in 1880, and has steadily gone down to .52. Oats was the same in 1916 as in 1890, but was lower *ad interim*. Rye and potatoes have remained rather constant, though the tendency is downward. The barley acreage has risen through the demands of the liquor interests, but may be expected to drop with the incoming of prohibition. Thus in the pre-war period from 1870, the acreage of three great cereals, corn, wheat and oats, is not a matter of congratulation, though production through the increased use of fertilizers, better varieties and more intense cultivation has been sustained.

The production history for corn in the decades from 1870 taking for the last point the average of the years 1915, 1916 and 1917, is 23.38, 29.43, 27.28, 27.90, 29.72, and 28.61 bushels. As a whole, then, corn production has just about kept pace with population. Wheat, the basis of national life, follows nearly the same course. The figures 6.01, 8.24, 7.24, 7.60, 7.23 and 7.59. Oats have risen sharply. The figures are 6.63, 8.65, 10.41, 10.49, 11.17, 14.39.

These figures, considering them from all angles, are not a cause for present pessimism. The increased production of 1918 and 1919, due to the stimulation of war prices, shows what may be done by intensive methods even with our present system of agriculture. Nevertheless, I ask you to note that as a whole our food production per capita from about 1880 or 1890 to the war period has slighly declined. And this is in face of a tremendous increase in the use of fertilizers, a widespread propaganda for better methods of cultivation which was not without its results, a constant influx of improved machinery, and a continuous production of new and better yielding varieties. There is but one conclusion. Diminishing returns in agriculture *are operating*, and with a continuously and rapidly increasing population they will become more and more in evidence.

The arguments that have been used concerning diminishing returns in agriculture are not negated by the fact that the United States is still exporting large quantities of food. Since the people of the United States do not at present eat all the food produced, many will say that all is well. This does not follow. The improvident individual may feast before he wants. The prodigal heir may have a high time before the reckoning comes. The business on the verge of bankruptcy may be running at the peak of production. No one denies that the productivity of the United States is at present beyond her needs. No one denies that this production may be increased very considerably. We do maintain that capital is being dissipated to show these results, that returns are lessening to such an extent that the food cost of living—barring the war disturbance—is bound to rise, and that certain portions of the country actually do feel the pressure.

It may be replied that decreasing returns in agriculture will be offset by increasing returns in non-agricultural industry. But, as Thompson has shown, it is not at all certain that manufacture presents increasing returns. It is but recently that cost accounting has taken into consideration the case of the workman, and it has not yet included the cost of maintaining our great city industrial systems with their streets, bridges and railways, their schools and hospitals, their banks and libraries, their bonded indebtedness. With these increased charges, what would be the balance sheet? The very fact of the immense bond flotations of our political units show that we are building upon the insecure assumption that the present social system is sound and permanent. Unless increasing returns for the country as a whole are in sight, our house is built upon sands. Let us give these matters their proper place when dealing with panaceas for social unrest. There can be no value in prescriptions which leave untouched the fundamental causes.

If pressure upon the means of subsistence is beginning to be felt in this relatively new country, if misery and suffering due to overcrowding is approaching—and who can face the facts and continue to doubt—what a dire prospect exists for the older countries of the world.[19] And a sad feature of the case is the fact that though there be a continuous emigration to those portions of the world where unexploited natural wealth still remains, but slight temporary relief will be afforded the countries from which the emigrants go. *Long before the sparsely populated lands are filled, in the next half century in such prosperous countries as our own, there must be a shift of population from the cities to the farms.* Coincident with this industrial change there must be a simplification and probably a lowering in what we are pleased to call the standard of living. Technical industry can not take the burden of this shift and still continue to furnish the whole of the people with the comforts and luxuries they have come to deem necessary. Contemplation of this fact is all that is necessary to show that at the same time there will be a continued lowering of the birth rate. The relation between these matters is not kept from the people. Their theories on the subject may be hazy, but direct pressure on existence is a great teacher. The birth rate will continue to go down, and immigration will be greatly restricted if not prohibited. Broadly speaking, this is a result not to be deplored. Why then is so much time, ink and paper used in decrying the declining birth rate? There is one real reason, but it is not the one acknowledged by greater population propagandists.

Economically the position of the French people in 1914, with a very slowly increasing population, was extraordinarily good. Thrift and industry had placed them in the fore-front of the nations of the world, and there was relatively little pressure upon the means of subsistence. They feared two things: first, immigration of peoples with lower standards of living and greater rates of natural increase, with resulting replacement of the native French; second, attack from the east. Both fears had a real basis as we know, and Leagues of Nations or of

[19] One of my colleagues has made the off-hand criticism that these conclusions do not hold because no allowance has been made for the "immense possibilities in the way of utilizing sea food." This criticism well illustrates the ease of refuting a statistical argument by using a statement which has no basis of fact. In the first place, the sea-food industry of the world is of little import as a factor in feeding the world's population. Making all due allowance for possible understatement in the statistical returns, the value of the sea-food production of the world is *less* than that of the production of poultry and eggs in the United States. In the second place, diminishing returns in this industry are indicated by the fact that the increase in capital employed during the last 20 years is very much greater than the increase of the returns in product.

Notions will not abate them. These apprehensions will always be bogies of small nations. The odd thing is that so many statesmen should encourage actual misery from over population to alleviate a fear of possible misery through aggression.

In a country such as the United States the second fear is groundless. With a proper preparation for war, an attack on the United States should not be considered seriously. Mere masses of people are not a menace as they once were, as the Germans and Russians have demonstrated. And we are big enough to take care of ourselves. The other fear is something more definite, but few give it any attention. The unacknowledged reason why the politician wants more people is to satisfy his longing for greater power, the hidden desire of too many capitalists is for cheap labor. The real objection to a declining birth rate is that it is always selective.

The selective birth rate in the United States is a subject on which much has been written, but on which there is little accurate information. The vital statistics of various states are meagre and rather untrustworthy. In fact even at the last report (1916),[20] the registration area included only about one third of the whole population. The crude birth rate for that year was reported as 24.8 and the crude death rate 14.7, leaving a natural increase of 10.1 per thousand; but the figures probably do not represent the facts. Neither death rates nor birth rates are reported in full, but the deficiency in registration of births is undoubtedly greater than that of deaths. It would not be a surprising matter if the real natural increase in the United States as a whole is about 11.5.

The negro birth rate[21] is put at 22.8 and the death rate at 24.4. Obviously these figures can not be accepted at their face value. Not only are the vital statistics registered for negroes known to be less accurate than those for whites; but no part of the real "black belt," where the negro is in his best environment, lies within the registration area. The figures are largely from cities where there is an extensive negro population, places in which numerous factors tend to lower the natural increase from that attained in the "black belt" even though the economic condition based on per capita wealth may seem higher. The census figures for 1910 give some idea of the discrepancy.

[20] Birth statistics for the registration area of the United States (1916). Second Annual Report. U. S. Bur. Census, 1918, pp. 96.

[21] The Negro Population in the United States, 1790–1915. U. S. Bur. Census, 1918, pp. 844.

In the previous decade the negroes increased 993,769, 11.2 per cent., and this may be taken as largely from natural increase, since there was an increase of only 20,003 foreign born, and this figure must be diminished by about 45 per cent. to allow for emigration. During the same period the whites increased by 22.3 per cent. The proportion of negroes in the population as a whole is decreasing, therefore, yet one can not help but feel that if all the data were at hand, the natural increase of the whites and the negroes would be found to be about the same. If venereal diseases are ever stamped out among them, and a reasonable degree of sanitation instituted, there is scarcely a doubt but that they will tend to supplant the whites, for the whites have kept their numerical superiority largely through immigration and a better knowledge of hygiene. Thus, since there were nearly 10 million negroes in continental United States in 1910, the color problem is not the negligible matter some of our northern sociologists would have us think.

Another fact which should be regarded seriously is that the mixed bloods are increasing much more rapidly than the pure blacks. There were nearly twice as many mixed bloods in 1910 as in 1890. In 1890 the mulattoes formed 15.2 per cent. of the negro population, in 1910 they represented 20.9 per cent. With the white blood comes greater intelligence, a lower death rate, and in all probability a higher birth rate. In time segregation and recombination of traits will result in a considerable number of people with negro blood who will pass for white.

It seems hardly necessary to point out the undesirability of this situation. The negro is a happy-go-lucky child, naturally expansive under simple conditions; oppressed by the restrictions of civilization, and unable to assume the white man's burdens. He accepts his limitations; indeed, he is rather glad to have them. Only when there is white blood in his veins does he cry out against the supposed injustice of his condition. White germplasm in a negro complex spurns its hopeless situation, as Humphrey[22] notes. Yet the result of such a wide racial intermixture is a mediocrity; which, owing to the numerous gametic differences linked and coupled in an infinite complexity of ways, will tend to remain a mediocrity till the end of time.

Concerning the potentialities of our white "Melting Pot," one is likely to say too much or too little. As a mere matter of statistics the country seems to be progressing fairly well. There is a somewhat greater proportion of foreign than of

[22] Humphrey, S. K., "Mankind," New York, Scribner, 1917, pp. 223.

native paupers, but that might be expected without great discredit to the former. In 1910 there were .88 per thousand native and 1.57 per thousand foreign-born prisoners and juvenile delinquents,[23] but in all probability the sins of the good American citizen did not find him out as often as might be desired. At the same period there were 1.69 per thousand natives and 4.05 per thousand foreigners in institutions for the insane. No doubt the terrific whirl of American life drove some of these newcomers mad, for the proportion is rather different in institutions for the feebleminded. The ratio there per thousand is, native 2.65, native of native parentage 1.70, native of foreign parentage 2.86, and foreign born, .93.[24]

In acquiring some slight knowledge of letters the foreigners coming to our shores have done well. In our native white population born of native parents 3.7 per cent. were unable to read and write in 1910, but although 12.7 per cent. of the foreign born were in the same predicament, hardly one tenth as many natives born of foreign or of mixed foreign and native parents are to be so classified.[25]

In spite of this somewhat unexpected showing from our recent emigrants, however, there are reasons for serious misgivings, misgivings sufficient to warrant us advocating such restrictions as to practically prohibit immigration for a period of time that will at least permit us to consider the subject in all its aspects. The examinations in the selective draft, the radical labor troubles now in full fruit, the Bolshevist propaganda, have shown how refractory are some of the ores in the melting pot and how poorly our fires have been tended.

We have developed too rapidly, and are experiencing acute growing pains in various portions of the anatomy of our body politic. It is troublesome and should be attended to, but it is not extremely serious. If we continue as in the past, we shall suffer indeed. We must come to realize that if we make the most of our grand heritage of democratic ideals left by the fathers of colonial days, we must change our tactics.

The point, it seems to me, is this. Our political legacy, our folkways, our Americanism, is North European, Northern Aryan, Nordic. Whatever one wishes to call it, its origin is

[23] Prisoners and juvenile delinquents, 1910. U. S. Bur. Census, Bull. 121, 1914, pp. 130.

[24] Insane and feeble-minded in institutions. U. S. Bur. Census, 1914, pp. 217.

[25] Illiteracy in the United States. U. S. Bur. Census, Bull. 26, 1905, pp. 54. Also 13th Census of U. S.

not in doubt. Our great men in all lines—statesmen, warriors, writers, scientists, inventors—came so largely from this ethnic mixture that if they are excluded but little is left. Some one once said: Take from France her hundred great ones, and where is France? We may paraphrase it thus: Take from Columbia her Anglo-Saxon sons, she is bereaved indeed. And is she not being dispossessed of her Anglo-Saxon stock? The birth rate of our foreign population, coming so largely now from eastern and southern Europe, is so much greater than that of the Anglo-Saxons that within a century the latter will be but a fraction of the whole.

It may be that the various ethnic mixtures recently acquired will do their full share toward contributing to the progress of civilization. There are many, however, who feel justified in maintaining that if immigration had been restricted in the middle of the nineteenth century, the country would be better off physically, morally, mentally and economically. There would be almost as many people within its limits, for the superior types of the early days would not have been forced to the wall by the avalanche of progeny begotten by the horde of aliens. Given the time these matters may right themselves, but it should not be forgotten that it is just such waves of immigration that overturn civilizations before there is time for readjustment.

We are entering such a period. We must fight for time, or accept an overturn of the present social order. No doubt it is desirable to have social changes; it is suicidal to allow a sudden economic chaos. Among biologists a defense of private property, free enterprise, and a competition which does not interfere with social order, is unnecessary. These things must be, in order to bring out the fittest to survive. At the same time there must be a regulation of the degree of social warfare or a reversion to savagery will result. People are much alike. The capitalist takes everything when he has the chance; the workman hopes to take everything when he is able. Obviously this natural law promotes progress; but in society even as in nature, the most rapid progress comes when the selective action is directed along certain channels and restricted to particular ends. The great effort, then, must be to direct it properly. Denying its existence is of little avail.

What is the answer? As I see it, it is this: First a severe restriction of immigration; second, education; third, equitable readjustment in many of our economic customs; last, but by no means least, rational marriage selection, a somewhat increased birth rate in families of high civic value, and among the rank and file a restriction of births commensurate with the family resources and the mother's strength.

Economically we can not afford a high birth rate, but it should be cut in the proper place. If this be done, it means a fall in the death rate, in the disease rate, in the proportion of misery and poverty. It means less child labor and illiteracy, less prostitution and venereal diseases. It means a healthy home life, larger production, greater economical freedom and therefore happiness. Anything else is merely reducing the fit to the level of the unfit.

If we have the brains, the energy and the courage to put through such a program there is some hope of escaping the whirlpool into which we are drifting. The ingredients in the melting pot are not all bad by any means, and—one may be thankful for it—they do not form an amalgam. Each and every ethnic contribution carries some hereditary factors making for a good or even a great individual. The result of the interbreeding of the next century will on the whole be mediocrities, as it has been in the past, but recombination will give here and there the individual with the characters that make for genius and progress will be assured. If we do not open our eyes on this problem of population, however, there will be troubles in the future which will make those of the present seem like the tempests of a teapot.

THE PROGRESS OF SCIENCE

LETHARGIC ENCEPHALITIS

Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, has presented to the National Academy what is known concerning a disease that has recently attracted much attention. In an abstract now published in the *Proceedings* Dr. Flexner states that in 1916 there arose in Vienna and possibly in other places in the Austrian Empire, cases of a peculiar disease a prominent symptom of which is lethargy. Because of this feature, which amounts at times to a condition of profound and prolonged "sleepiness," the disease receives the popular name of sleeping sickness. And yet it was quickly recognized as being wholly distinct from the well-known African sickness, the inciting microorganism of which is a trypanosome. The structural or histologic basis of the Austrian disease is an inflammation, chiefly located in the gray matter of the base of the brain, or technically an encephalitis. Because of the peculiar symptoms and of the lesions, von Economo of Vienna who first described the disease gave it the name of lethargic encephalitis.

About two years later, that is, in 1918, outbreaks of the same disease were reported from England and France. A little later the disease appeared in the United States, and published reports now indicate that it has a wide distribution over the world. When the disease was first recognized in Vienna, it was supposed to be a form of food (sausage) poisoning; and the early cases in England were attributed to botulism. This mistake is quite explicable: among the prominent symptoms are paralyses of the ocular and facial muscles, which arise also in food poisoning. Because of war conditions, both the countries mentioned were using preserved foods to an unusual degree; hence the inference.

Because of the accompanying paralysis and subsequently because of certain peculiar characteristics of the histological changes in the brain, a discussion arose whether the disease was not merely a peculiar form of poliomyelitis or infantile paralysis, which has prevailed epidemically and fitfully in Europe and America for a decade or longer.

The Rockefeller Institute has had wide experience with poliomyelitis during ten or twelve years; and since the winter of 1919 material from numbers of cases of encephalitis have been referred to it. On the basis of the studies made, it is quite safe to say that the diseases —lethargic or epidemic encephalitis and epidemic poliomyelitis—are distinct. A striking difference relates to the transmissibility of the one to lower animals (monkeys) and not of the other. Moreover, the actual histological changes or lesions in the two diseases show striking differences, both of distribution in the central nervous organs and in minute structure. Lethargic encephalitis is surely an infectious disease, but its inciting microbe is still undiscovered.

The question arises whether encephalitis has been observed before, or is to be considered as being a new disease, in the sense that it had never before been recognized and described. A brief account exists of an outbreak of a so-called "sleeping sickness" in the neighborhood of Tübingen in Germany in the year 1712; and what appears to be a similar malady more widely distributed in Austria, Italy, and Switzerland in 1890. The first appearance of the present epidemic and the location of the 1890 outbreak coincide territorially. It is not possible to state absolutely that the disease originated this time in Vienna; under war conditions its occurrence in outlying rural districts might well have been overlooked. But there is nevertheless basis for the view proposed tentatively, namely, that an endemic focus of a peculiar and specific form of encephalitis exists in Southeastern Europe, from which the present wide occurrence of the disease took origin.

THE WIRELESS TELEPHONE

The practical value of research in the field of pure science was vividly demonstrated in a lecture on "Scientific Discovery and the Wireless Telephone," presented at the American Museum of Natural History by Dr. Robert W. King, engineer of the American Telephone and Telegraph Company. Dr. King illustrated his lecture by demonstrations and models both of discoveries leading up to the wireless telephone and of the wireless telephone itself as employed during the war for airplane communication. The exhibit of models and apparatus installed in connection with the lecture will remain at the museum during May and June. It was arranged by the American Telephone and Telegraph Company and the Western Electric Company in cooperation with the American Museum of Natural History and the New York Academy of Sciences. The lecture and exhibit are the first of a series included in the peace-time program launched by the National Research Council. They have already been presented at Washington, where they aroused marked interest.

Dr. King's lecture traced the history of radio telephony as a development of scientific theories which, at the time of their discovery, seemed wholly removed from the every-day life of the world, but which a little later were to revolutionize that life. With the work of Hertz in the last half of the nineteenth century the broad general principles underlying the new science of radio communication were completely established. It has remained for scientific men of our own generation to devise the means for controlling the production of the electromagnetic waves in such a manner as to make possible the sending of intelligible messages over long distances and for the receiving of such messages. In this connection there are countless devices, all of the utmost practical value, yet almost without exception adaptations of discoveries in the field of pure science.

Comparing the working of the wireless telegraph with that of the wireless telephone, it will be seen that to send dots and dashes out through space all that is necessary is to interrupt the formation of the electric waves at the proper times, while in transmitting actual speech not only must the amplitude of the electric waves be varied continuously rather than abruptly, but the electric waves must be so modulated as to transmit the particular sound waves sent out by the voice. Such an oscillatory electric current upon its arrival at the receiving station, is caused to pass through a telephone receiver which accordingly emits the words of the voice in the same fashion as in the common telephone. In this way a reproduction of human speech can be carried without wires over an ocean or a continent. This remarkable fact was actually demonstrated in September, 1915, when the Engineering Organization of the Bell Telephone System, after years of silent preparation successfully sent a wireless telephone communication from Washington, D. C., eastward to Paris and westward to Honolulu, the latter being a distance of 4,900 miles. On the same occasion, speech was transmitted over a standard telephone circuit from New York to Washington, where it was automatically amplified and relayed to the radio apparatus and thence projected through space across the continent to San Francisco.

It is in such a combination with the wireless telegraph that the greatest usefulness of the wireless telephone will probably be found to lie. Through the happy union of the two new arts of communication, spoken messages can be sent from airplanes, ships, moving trains and points on land or water where the installation of wires or cables is impracticable, to a convenient receiving station, whence they can be relayed by wireless telegraphy to more distant points. Doubtless, also, if satisfactory methods are found for eliminating atmospheric disturbances and preserving secrecy, the wireless telephone will to some extent be used for the handling of trans-oceanic messages.

SCIENTIFIC PUBLICATIONS IN ENGLISH FOR THE NATIONS OF CONTINENTAL EUROPE

Two movements have been initiated, one in the United States and one in England, for the supply of books and journals to European countries. In this country an appeal is signed by Felix Adler, James R. Angell, Franz Boas, Charles W. Eliot, J. Cardinal Gibbons, Arthur T. Hadley, David Starr Jordan, Harry Pratt Judson, E. H. Lewinski-Corwin, A. Lawrence Lowell, John Bassett Moore, Henry Fairfield Osborn, George Foster Peabody, M. I. Pupin, Jacob Gould Schurman, Ellery Sedgwick, F. J. V. Skiff, Munroe Smith, Antonio Stella, Henry Suzzallo, Harlan F. Stone, William H. Taft and F. A. Vanderlip.

They say:

> Owing to the depreciated currency of Europe and the financial difficulties in which many European nations find themselves, the publication of some European serials has been temporarily discontinued, others have decreased in size, while the publication of still others is irregular. Furthermore, the purchase of American books at the present rate of exchange is practically impossible.
>
> Since it is essential for the intellectual life of mankind, that students of all countries should be in close touch, and since it seems of importance to America that the results of our intellectual activities should be known, the undersigned urge all publishers, publishing institutions and publishing societies to exchange their publications on the most liberal terms with libraries, publishers, journals and publishing institutions and societies of all European countries, disregarding for the near future the question whether the amount of printed matter received in exchange corresponds with the amount sent.

From England it is proposed to establish in Central Europe under British-American auspices libraries of recent English books indispensable to university teachers. The work is being organized on a broad, non-political, non-sectarian basis, so as to enlist the widest possible cooperation. These libraries will supply on loan books needed by the faculties of the different universities in Central Europe. They will be under the charge of British and American representatives, and committees of the foreign universities will be asked to superintend the local administration. A committee of the six most im-

WILHELM PFEFFER.

The distinguished Physiological Botanist of the University of Leipzig who has died at the age of seventy-five years. The photograph by C. Bellach was taken when Professor Pfeffer was fifty-four years old.

portant learned societies in Germany and Austria has been formed for the carrying out of the plan which, in addition to the loan library, will include a system of exchange of publications and duplicates between any libraries and institutions willing to cooperate. The preliminary statement of the trustees says:

> By thus taking the initiative in extending the hand of fellowship to colleagues in former enemy countries, British and American scholars are seizing a timely opportunity of helping to heal the wounds of the war and of exemplifying in a practical and convincing way the true "international mind."

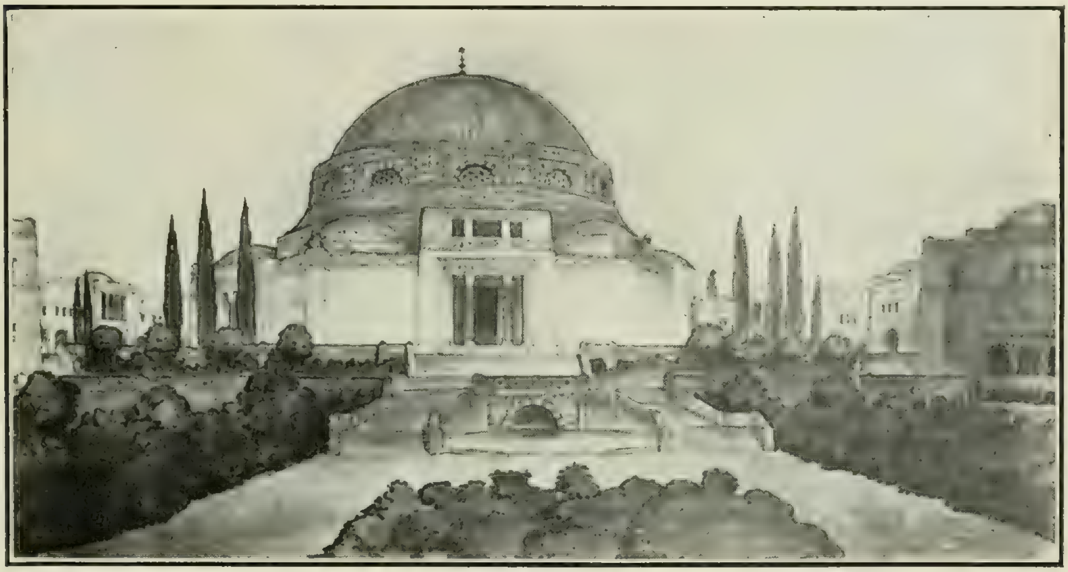
Viscount Bryce, Lord Robert Cecil and other English public men have expressed their approval of the plan and have promised their cooperation in carrying it out. The supporters of the plan in Great Britain include: Gilbert Murray, Oxford; A. E. J. Rawlinson, Oxford; C. S. Sherrington, Oxford; Walter Raleigh, Oxford; A. E. Shipley, Cambridge; J. J. Thomson, Cambridge; A. S. Ramsay, Cambridge; Joseph Larmor, Cambridge; Horace Darwin, Cambridge; W. B. Hardy, M.A., Cambridge; Alfred Hopkinson, Glasgow; Col. E. H. Hills, Woolwich; Henry A. Miers, Oxford; Alex. Hill, Cambridge; George Paish, London; Rickman G. Godlee, London, and Michael Sadler, Leeds.

University teachers in the United Kingdom and America are requested to give their approval and cooperation to the plan by sending their names to the secretary, Mr. B. M. Headicar, librarian of the London School of Economics (University of London), Clare Market, London, W.C.

SCIENTIFIC NOTES

We record with regret the death of A. J. Chalmers, lately director of the Wellcome Research Laboratories at Khartum; of J. S. MacArthur, the English industrial chemist; of Dr. E. Schwalbe, director of the pathological institute at the University of Rostock, and of Pier Andrea Saccardo, the distinguished mycologist and professor emeritus of the Royal University of Padua.

Members of the National Academy of Sciences have been elected as follows: Dr. James Rowland Angell, University of Chicago and the National Research Council, president-elect of the Carnegie Corporation, psychologist; Dr. Henry Prentiss



Main Building of the Hebrew University being constructed on the Mount of Olives, Jerusalem.

Armsby, Pennsylvania State College, physiological chemist; Dr. Wilder D. Bancroft, Cornell University and the National Research Council, chemist; Dr. Hans F. Blichfeldt, Stanford University, mathematician; Dr. A. J. Carlson, University of Chicago, physiologist; Dr. William Duane, Harvard University, physicist; Dr. Lewis R. Jones, University of Wisconsin, plant pathologist; Dr. Elmer Peter Kohler, Harvard University, chemist; Dr. Charles K. Leith, University of Wisconsin, geologist; Dr. Clarence Erwin McClung, University of Pennsylvania and the National Research Council, zoologist; Dr. Elmer V. McCollum, the Johns Hopkins University, physiological chemist; Dr. George Washington Pierce, Harvard University, physicist; Harris J. Ryan, Stanford University, electrical engineer; Dr. Joel Stebbins, University of Illinois, astronomer, and Dr. Bailey Willis, Stanford University, geologist.

THE fourth annual meeting of the Pacific Coast Division of the American Association for the Advancement of Science will be held at the University of Washington, Seattle, beginning on June 17. Addresses will be made by President Henry Suzzallo, of the University of Washington, and Professor John C. Merriam, dean of faculties of the University of California, president of the Pacific Coast Division. Morning sessions will be devoted to meetings of the affiliated societies, the Western Society of Naturalists, Pacific Fisheries Society, American Physical Society, Astronomical Society of the Pacific, Cordilleran Section of the Geological Society of America, Pacific Coast branch of the Paleontological Society, American Phytopathological Society, San Francisco section of the American Mathematical Society, Seismological Society, American Chemical Society, Cooper Ornithological Club, Ecological Society of America and the Society of American Foresters.

INDEX

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