this exceedingly interesting question, for so far as I know the literature, not one case of spore-formation has been carefully investigated and most cases of parthenogenesis insufficiently. And yet such investigations, particularly in the lower plants and animals, would be a profitable and important work.

In my summary I have not mentioned the budding and the fission of the multicellular animals and the so-called 'vegetative reproduction' of plants. We commonly unite these processes with the budding of the Protozoa and the spore-formation of the Algæ, under the name of asexual reproduction. I have considered them only briefly as new acquisitions of multicellular organisms. In 'vegetative reproduction' whole multicellular stocks are set free from a mother animal which has rapidly increased in size. The phenomenon presents the greatest diversity. The budding of the Tunicates is quite different from that of the Bryozoa or Hydroids or from the fission of the Annelids. The diversity in the forms of vegetative reproduction is still greater in plants. The investigations in the past twenty years have also proved that the division and budding of the Metazoa do not follow the laws laid down by the germ layer theory. In this respect they resemble regeneration. The whole matter will be a self-evident phenomenon if we accept the view of reproduction which I have set forth above and recognize in the division and budding of the multi-cellular animals adaptive phenomena which have come about in the several groups independent of their development. These processes of asexual reproduction are well named by the botanist 'vegetative reproduction.' If they are more common in the lower than in the higher forms it is because the higher organization sets a limit to the vicarious substitution of one part for another. Similar conditions therefore underlie vegetative reproduction and regeneration and there are many analogies between the two processes. It is worth noticing that in the lower plants, where spore-formation is very common, 'vegetative reproduction,' if we use the term as we have just defined it, is not present. Stocks which have been accidentally broken off from the threads of Algæ can, it is true, develop further, but under natural conditions the Algæ seldom make use of the process for reproduction.

Winterton C. Curtis.
Johns Hopkins University.

---

*Study of the Correlation of the Human Skull.**

The substance of this paper was a thesis for the London D.Sc. degree; it was shown to Professor Pearson, at whose suggestion considerable modifications were made, and a revision undertaken with a view to publication.

In order to deal exactly with the problem of evolution in man it is necessary to obtain in the first place a quantitative appreciation of the size, variation and correlation of the chief characters in man for a number of local races. Several studies of this kind have been already undertaken at University College. These fall into two classes, (i) those that deal with a variety of characters in one local race, and (ii) those which study the comparative value of the constants from a variety of races. Thus Dr. E. Warren has dealt with the long bones of the Naqada race,† Mr. Leslie Bramley-Moore has compared the regression equations for the long bones from a considerable number of races in a memoir not yet published, Professor Pearson has dealt with the regression equations for stature and long bones as applied to a

* 'Data for the Problem of Evolution in Man,' No. VI. By Alice Lee., D.Sc., with some assistance from Karl Pearson, F.R.S. Abstract read before the Royal Society of November 15, 1900.

† *Phil. Trans.*, B, Vol. 189, p. 135.

variety of races;* Miss A. Whitely has studied the correlation of certain joints of the hand,† and is investigating the correlation of the bones of the hand in a second local race; Miss C. D. Fawcett has made a long series of measurements on the Naqada skulls, and correlated their chief characters; the present memoir, on the other hand, deals with only a few characters, in the skull, comparing, however, the results obtained from a variety of local races.

It is thus related to Miss Fawcett's work much as Mr. Bramley-Moore's to Dr. Warren's, *i. e.*, it endeavors, by selecting a few characters and testing them, to ascertain how far results obtained for one local race are valid for a second. In Professor Pearson's memoir on the reconstruction of the stature of prehistoric races, results obtained from one local race were then extended to a great variety of other races. The degree of accuracy in this procedure can only be fully ascertained when the data now being collected in both English and German anatomical institutes are available for calculation.

The skull, however, differs very widely from the stature and long bones; for while these have a very high degree of correlation in all local races, the chief characters of the skull are very loosely correlated, and such correlation as they possess varies in a remarkable manner with sex and race. This was first indicated by Professor Pearson;‡ it has been amply illustrated in the measurements of Miss Fawcett, and is confirmed in a recently published memoir by Dr. Franz Boas. It may be said that this want of correlation in the parts of the skull is the origin of its great importance for the anthropologist; it is the source of its personal and racial individuality. But this anthropological advantage, is, from the standpoint of organic evolution, a great disadvantage. Cuvier introduced the conception of correlation with the idea of reconstructing from a single bone the whole skeleton and even the outward form of an extinct animal, but the great want of correlation between the parts of the skull, and between the skull and other parts of the human skeleton, renders quantitative reconstruction — and this is the really scientific reconstruction —of one character of the skull from a second, or of the skull and parts of the skeleton from each other extremely difficult, if not impossible, for all but a very few characters.

Among these characters one of the most feasible to deal with, and one of the most useful, is the capacity of the skull. This is correlated to a fairly high degree (although to nothing like the same extent as the long bones among themselves) with the maximum length and breadth, with the total and auricular heights, and with the horizontal and vertical circumferences of the skull. The present memoir deals in the main with the problem of the reconstruction of the capacity from these characters.

Three fundamental problems arise in the theory of reconstruction, *i. e.*, the determination of the probable value of an unknown character from a known and measurable one, or from several such. Namely:

I. The reconstruction of the individual from data for his own race.

II. The reconstruction of the average value of a character in one local race from data determined for a second local race.

III. The determination of the probable value in an individual of characters not measurable during life from characters which are measurable.

These three problems are all dealt with for the special character capacity of the skull in the present paper. Their impor-

* *Phil. Trans.*, A, Vol. 192, p. 169.

† *Roy. Soc. Proc.*, Vol. 65, p. 126.

‡ *Phil. Trans.*, A, Vol. 187, p. 279, and *Roy. Soc. Proc.*, Vol. 60, p. 495.

tance may be indicated by the following considerations:

(*a*) Many, especially of the more ancient and accordingly of the more interesting skulls, are too fragile or too fragmentary to allow of their capacity being directly determined.

(*b*) The methods for directly determining capacity are still not only very diverse, but divergent in result, and from the physical standpoint, crude and inexact. In the concordat of the German craniologists—the *Frankfürter Verständigung*—the point was left for future consideration, and so it has remained for many years. The capacities of series of skulls determined during the past forty years in France, England and Germany are, we are convinced, not comparable, at least if the argument from the comparison is to depend on a difference of 30 to 40 cm.[3] While the same observer using different methods may be trained to get results within 4 to 6 cm.[3] for the same skull, different observers, equally careful, using the same method, will easily get results for the same series diverging by 20 to 30 and even more cubic centimeters. Shortly, the personal equation—involved in the packing in the skull and in the measuring vessel—is very large.

Accordingly a regression equation for the capacity as based on external measurements may, if deduced from a sufficiently large range of series measured by careful independent observers, give results fairly free from the error of personal equation and this sensibly as correct as, or more correct than, direct measurement when we require the mean capacity of a series.

(*c*) It is impossible to obtain a large series of skulls belonging to known individuals with a classified measure of intellectual ability. Actually we have only a few skulls of men of great intellectual power, sometimes preserved because they were large, and to compare with these the skulls of the unknown and often the ill-nourished, which reach the anatomical institutes.* Accordingly it is an investigation of considerable interest to compare the *probable* capacity of the skulls of living persons with their roughly appreciable intellectual grade. It is only by such a comparison that we can hope to discover whether the size and shape of the skull is to any extent correlated with brain power.

In the course of the memoir it is shown that the auricular height of the skull is a better measurement for determining skull capacity than the total height; that the circumferences of the skull, while highly correlated with its capacity, give regression equations which vary widely from one to another closely-allied race; that linear regression equations involving length, breadth and auricular height, while giving fairly good results for individuals within the local race, have very divergent coefficients as we pass from local race to local race; that the cephalic index has very little correlation with capacity at all; as a rule what there is may be summed up in the words: In a brachycephalic race the rounder the skull the greater the capacity, in a dolichocephalic race the narrower the skull the greater the capacity—the greater capacity following the emphasis of the racial character; finally, that the correlation of capacity with the triple product of length, breadth and height gives a regression equation which is fairly constant from local race to local race, and is accordingly the best available.

From this and other equations individual and racial reconstructions are made, and the deviations between the actual and predicted capacities in randomly chosen series of skulls are tabulated. The mean error made in the reconstruction of the individual capacity by the best formulæ is 3 to 4

* This argument applies also, in even an intensified degree, to the determinations of brain weight.

per cent., the maximum error, although of course infrequent, may even be ten per cent. For the reconstruction of the mean capacity of a race, the mean error is about 1.2 per cent., with a maximum error of 2.5 per cent. If these errors appear large to the craniologist, we would remind him that his search for an absolutely correct formula giving cranial capacity from external measurements is the pursuit of a will o' the wisp. The theory of probability shows us exactly the sort of errors such formulæ are liable to, and teaches us how to select the best. The whole basis of the theory of evolution, the variability of one character, even with fixed values for a number of others, would be upset if any such absolute formula were forthcoming. What we have to do is to select a few organs as highly correlated as possible, but, having done this, it has been shown elsewhere that we shall not sensibly decrease the error of our prediction by increasing the number of organs upon which the estimate is based.* Accordingly we do not believe that sensibly better reconstruction formulæ than those found will ever be forthcoming, for, as we have already observed, we know from Miss Fawcett's wide series of skull correlations that we have practically chosen the organs of the highest correlation. Better data for determining the equations will undoubtedly be available as further craniological measurements are made, or as the great mass already made are quantitatively reduced.

In the last place we turn to the third problem: the reconstruction of the capacity of the living head. The memoir contains tables of the skull capacity of some sixty men, and also of some thirty women, whose relative intellectual ability can be more or less roughly appreciated. It would be impossible to assert any marked degree of correlation between the skull capacities of these individuals and the current appreciation of their intellectual capacities. One of the most distinguished of continental anthropologists has less skull capacity than 50 per cent. of the women students of Bedford College; one of our leading English anatomists than 25 per cent. of the same students. There will, of course, be errors in our *probable* determinations, but different methods of appreciation lead to sensibly like results, and although we are dealing with skull *capacity*, and not brain weight, there is, we hold in our data, material enough to cause those to pause who associate relative brain weight either in the individual or the sex with relative intellectual power. The correlation, if it exists, can hardly be large, and the true source of intellectual ability will, we are convinced, have to be sought elsewhere, in the complexity of the convolutions, in the variety and efficiency of the commissures, rather than in mere size or weight.

* *Phil. Trans.*, A, Vol. 190, p. 466.

AMERICAN ORNITHOLOGISTS' UNION.

THE Eighteenth Congress of the American Ornithologists' Union convened in Cambridge, Mass., Monday evening, November 12th. The business meeting was held in Mr. William Brewster's Museum, and the public sessions, commencing Tuesday, November 13th, and lasting three days, were held in the Nash lecture room of the University Museum.

Dr. C. Hart Merriam, of Washington, D. C., was elected President; Charles B. Cory, of Boston, and C. F. Batchelder, of Cambridge, Mass., Vice-Presidents; John H. Sage, of Portland, Conn., Secretary, and William Dutcher, of New York City, Treasurer. Frank M. Chapman, Ruthven Deane, E. W. Nelson, Witmer Stone, Drs. A. K. Fisher, Jonathan Dwight, Jr. and Thos. S. Roberts were elected members of the Council. By a provision of the by-laws, the Ex-Presidents of the Union, Dr. J. A. Allen and Messrs. William Brewster, D. G. Elliot