surgeon was forced to become a more practical bedside man than the top-heavy scholastic internist. The Levitical code of sanitation (isolation of suspects in eight contagious diseases), and Hindu (non Roman) surgery also gained a status. Modern science differs from Greek and medieval science, however, not so much in aims or results, as in processes and methods; and here we have "certain new factors of an order the world has not before seen." Except in the mathematics, the essence of which is to give steps and processes, the Greek scientist gave only conclusions and concealed his proofs, his findings being in the Lucretian phrase "*obscura reperta.*" Concerning this, Singer says (p. 20):

> Ancient mathematics, like everything else that has come down to us from antiquity, have of course suffered from the accidents of time, but the obscuring power of time is a mere light veil compared to that heavy impenetrable curtain that the Greeks have themselves drawn over their biological works.

The medieval scientists (witness the alchemists or Leonardo's mirror-written physiology) had the same tendency. But we pride ourselves upon the fact that our scientific monographs are devoted mainly to definite proofs of the author's propositions. The Greeks had no instruments of precision because, being speculative philosophers, they felt no necessity for proofs. Thus, while mathematics, however interrupted by the Dark Ages, is a scientific continuum, medieval science, like Greek science, is too frequently a solution of continuity, while the continuity of modern science is insured by simple preservation of records. The only danger threatening modern science, as Singer sees it, is in the isolation of scientific workers through the extreme and complex specialization of their subjects, making one branch of science unintelligible to the followers of another. The best way to obviate this danger is through the broad study of the historical evolution of science as such, for this "experimental" method will evade the pitfalls which befell Whewell and Comte, viz., the arbitrary concept of a rigid orthodoxy in science, based upon a quasi-medieval hierarchy of all the sciences. The history of science is not secular or sociological history, but the cultural history of mankind, the bases of which are anthropology and psychology. Through this branch of study we may clarify our own concepts, document and preserve our records, correlate our findings and so establish a continuum with the future and the past.

The finely wrought argument (Singer at his best) concludes with the thought, familiar to us in certain well-known verses of Lucretius, that the distinctive hope and glory of the science of our age is "that it will place in the hands of the inheritors of our civilization and our thought, whoever they may be, an instrument that will enable them to carry on our work from the point at which we leave it." No one can read this inspiring lecture without a heightened, clarified perception of the superior worth of modern science and the dangers which beset it. In the lecturer's own words:

> Our scientific system, of its nature, claims an independence of all race, nationality or creed. It is of all studies the most truly international. The scientific man may, better than most, claim with St. Paul that he is a citizen of no mean city, that he is the true citizen of the world.

F. H. GARRISON
ARMY MEDICAL MUSEUM

SPECIAL ARTICLES

THE PRODUCTION OF ARTIFICIAL HERMAPHRODITES IN MAMMALS

DURING the last ten years especially, there has been a decided impetus towards the analysis of sexual conditions, in animals, that has largely centered itself around a study of the physiology of the sex glands by means of transplantation experiments. From 1910 to 1913 Steinach reported his remarkable results obtained from sex gland transplantation in which one sex gland had been transferred to young castrated animals of the opposite sex (rats and guinea-pigs). The results in brief were: (*a*) masculinization of female animals by implanted testes (*i. e.*, the young female animal, after receiving the transplant, developed into a male-like animal as indicated

by somatic changes—weight, length, skeletal changes, hair coat—as well as by psychic behavior—temperament, and reactions toward animals of the opposite sex); and (*b*) feminization of young male animals by the implantation of an ovary, with corresponding results.

One point of especial interest, in this work, is in reference to the apparent antagonism of the sex glands (considered as hormone antagonism) when brought together in the same individual. Steinach was unable to obtain either a growth or persistence of an implanted sex gland *unless the gland of the host (gland of the opposite sex) was removed before the implantation was made.*

Following Professor Lillie's study of the free-martin, and at his suggestion, I began in 1916 a study of the interrelation of the sex glands that very soon led to a reinvestigation of the conditions considered by Steinach. In his study of cattle twinning, Lillie found that in a very large percentage of cases the twin fetal circulations are connected through an anastomosis of the allantoic blood vessels, as a result of the fusion of the chorionic vesicles. In correlation with such a condition, and only when the twins were male and female, the ovarian development was suppressed in the female of the pair; also, in many cases, there was an apparent superposition of male secondary sex organs upon the "determined" female sexual condition. In offering an explanation of this unique condition, Lillie suggested the possibility of a hormone antagonism with a dominance of the male secretion[1] (*i. e.*, theoretically a secretion of the testis, carried in the blood from the male to the female of the pair, may be responsible for the accompanying abnormal condition found in the female); the development of the male sexual apparatus suffers not at all from the unusual condition. If the twins are homosexual—*i. e.*, two males or two females—the reproductive system of each is entirely normal.

I have previously reported[2] the progress of the investigation undertaken and have offered a few criticisms of Steinach's conclusions. The immediate cause for this preliminary report, upon other aspects of the problem, is the appearance of a paper by Knud Sand[3] relative to the possibility of obtaining a persistence or growth of both kinds of sex glands in the same host without any apparent ill effect to either gland (a hermaphroditic condition); this paper is practically a summary of a larger monograph published in Danish.

Sand, on the whole, supports the work of Steinach but has reflected some discredit on the idea of sex gland antagonism. In a later paper Steinach reported having succeeded in obtaining subcutaneous growth of both kinds of sex glands *when these were grafted simultaneously on the same infantile castrated male animal,* and Sand, repeating the same technic, obtained an hermaphrodite animal both somatically (both glands persisted, and the rudimentary mammary glands of the male animal underwent considerable hypertrophy) as well as psychically (the animal is described as behaving both as a male and as a female). He also implanted an ovary within the substance of a testis ("Ovario-testis") and obtained a (normal) persistence of both glands. It is difficult, however, to clearly understand all of the statements in this paper, for after describing such a persistence of an ovarian graft within a testis which he claims has been left "in their natural position," he asserts that:

> *Neither did I ever succeed in a real ingrafting of the heterological gland on non-castrated animals,* whereas there was, as mentionel before, a positive result if the gonads had immediately been brought under somewhat the same conditions by simultaneous transplantation on the same animal, or by the intimate union formed by the production of ovario-testes.[4]

Sand also agrees with Steinach in his ideas of psychical changes as a result of gonad transplantation into previously castrated young animals of the opposite sex; he uses as a criterion of sex his interpretations of certain features of the behavior of such an animal.

[1] F. R. Lillie, *Jour. Exp. Zool.*, Vol. 23, 1917.

[2] C. R. Moore, *Jour. Exp. Zool.*, Vol. 28, Nos. 2 and 3, 1919.

[3] *Jour. of Physiology*, Vol. 53, December, 1919.

[4] Italics mine.

In my former papers I have discussed certain factors used as definite indicators of maleness and femaleness, and have attempted to point out the difficulty of properly interpreting the observations. With considerable reticence I was inclined to give some weight to psychical behavior in cases of the most extreme type of reactions; but I wish again to emphasize the absolute unreliability of closely graded indications of psychical behavior of rats and guinea pigs as an indication of their sexual nature. It is, in my opinion, going to an extreme when one asserts as does Sand:

> This somatic hermaphroditism was combined with a decided bisexualism of the psycho-sexual character, in that the animal showed, *even during the course of a single hour, momentary change from female to a decided male character*, according to the animals (males, newly-born young ones, females) with whom it was brought into contact.[5]

Sand's general conclusions in reference to sex gland growth seem entirely superfluous in the light of my own results. In explaining his failure to obtain growths of ovarian grafts in *non-castrated infantile* male animals he assumes a rather indefinite type of "Immunity" on the part of the host, towards the implanted tissue, and explains it as follows:

> In every organism are found certain substances which are necessary for the sexual glands, and these substances the latter try to obtain to the greatest possible extent. The normally situated non-transplanted gonads have the best chance of being able to absorb these substances, for which reason heterological (perhaps also homological) gonads, transplanted on normal organisms, can not get enough of these substances and therefore perish. Homological and heterological gonads, which have been transplanted at the same time to the same organism, are both able to grow in, having both about the same opportunity of absorbing the substances.
>
> Further the phenomenon that ovaries ingrafted in the testes find good conditions for developing there, can probably be explained by a similar theory, in that the substance of the normal male organism, necessary for the gonads, are perhaps stored up in the testes, both kinds of gonads thus being able to make use of them.

[5] Italics mine.

So far as the persistence and growth of rat gonads is concerned, this theory is entirely unnecessary for I have been able to obtain growths of ovarian grafts, subcutaneously, intra-muscularly, and intra-peritoneally, and without difficulty, in young male rats one of whose sex glands was intact and normal.

This part of my work was begun in 1917 and some animals bearing transplants are still living; but a detailed account of this work is nearing completion and will appear as the third paper of a series "On the Physiological Properties of the Gonads as Controllers of Somatic and Psychical Characteristics."

I have obtained persistence of both types of sex glands grafts after transplantation into young animals of the opposite sex, one of whose sex-glands had been removed to furnish material for other grafts, while the second gland of the host remained undisturbed. In the case of the ovary, the graft, after persisting eight and one half months in a male animal with an intact testis, presents all the features of a normal ovary of similar age excepting corpus luteum tissue and the presence of a larger number of atretic follicles. Normal follicles of all sizes are present—primordial follicles, more mature ones showing the beginning of the follicular cavity, mature follicles, and even those showing polar body formation in the ovum. The follicles seem not, however, to go on in their normal behavior to ovulation and corpus luteum formation, but undergo atresia. The fate of a follicular mass can be traced to its complete conversion into interstitial material. In this behavior of the follicles of the grafts, they are very similar to corresponding structures of the young female sex gland before the age of sexual maturity.

With the testicle grafts the results are not quite so striking due to the fact that mammalian testis transplantations, without exception so far as I am aware, results in the loss of the germinal epithelium. The grafts resemble considerably a cryptorchid testis in that both retain the well-rounded seminiferous tubules, but all that remains of a cellular character are Sertoli cells. The same disappear-

ance of the germinal epithelium, however, has been noted in case of ligation of the vas deferens without further disturbance of the testis. The testis graft does persist after transplantation in a female, with an intact ovary, and it is as normal as autoplastic testicular grafts, either with or without previous castration.

These observations show definitely that a sex gland can be successfully transplanted to an animal of the opposite sex which retains one normal gonad. Positive cases are of much more significance than any number of negative cases and leave no question as to whether the two glands can exist in a functional condition within the same organism at the same time. A male rat with one testis will function as a normal male during the time it is carrying two ovarian grafts as an integral part of its somatic structure; both of these grafts remain essentially normal, showing all grades of maturity of follicles, even after existence, in the subcutaneous tissues of the male, of eight and one half months.

A discussion of these observations will be taken up more fully when the completed work appears.

Carl R. Moore
The University of Chicago

STATIC REJUVENATION

For several years the writer has been making a systematic detailed study of the driftless area of southern Indiana, and has now in preparation a paper on the physiographic development of the Knobstone cuesta region lying between the Muscatatook and Ohio rivers. This particular region offers one or two problems of more than local interest, and the interpretation of one of these will be briefly stated here.

It appears that some time about the middle of the Tertiary the entire region was reduced to a peneplain (Highland Rim, or Lexington peneplain). The region was then rejuvenated by uplift. Dissection of the uplifted peneplain followed. Dissection was fairly complete near the major streams, and, in the regions of soft rocks, local areas were reduced to base-level. These locally reduced plains indicate that the uplift amounted to something like 175 feet. The region was again uplifted and dissection was renewed or continued. The Tertiary uplifted peneplain is now represented by remnants which are as much as 300 to 500 feet above the present local base-level. The New Albany shale and the lower part of the Knobstone areas were reduced to a lowland in contrast to the region west of the Knobstone escarpment. The lowland plain, stretching north from Louisville consists of a flat to undulating plain varying from 430 feet in the valleys near the Ohio River to something like 600 feet in elevation on the low divide between Silver Creek and the tributaries of the Muscatatook River. Since there are a large number of hills and flat interstream tracts at an elevation of about 500 feet at the south and coming up to about 600 feet near the above mentioned divide to the north, it has been stated that a local peneplain was formed at that level.[1] The writer concurs in the belief of a base-leveled plain of local area, and that its further development was terminated by rejuvenation. The rejuvenation, however, was not necessarily brought about by uplift. The dissection of the plain was very likely brought about by drainage changes made near the beginning of the Pleistocene. The present Ohio River is a large stream made up of a number of former drainage basins which were more or less destroyed or deranged by combination into a large major stream approximately skirting the outer limits of glacial advance. A very much smaller stream than the present occupied this territory near Louisville. It was able to reduce the area of soft rocks nearly to base-level, but it had a much steeper gradient than the much larger present Ohio. When the present Ohio invaded the basin of the much smaller pre-glacial stream the local peneplain was statically rejuvenated, due to the sinking of the larger stream into the plain on account of its ability to possess a much lower gradient in its grade condition. Such

[1] Chas. Butts, "Geology of Jefferson Co., Ky.," Ky. Geological Survey, 1915, pp. 201–203.