always well nitrified and fairly stable. The average analysis of this effluent is shown in the following table, of many analyses made during the year:

TABLE VII.—PARTS PER 100,000.

Rate—gallons per acre daily	1,820,000
Color	.5700
Ammonia—	
Free	1.7400
Albuminoid	.1392
Chlorine	8.6100
Nitrogen as—	
Nitrates	2.7600
Nitrites	.0071
Oxygen consumed	1.0800
Bacteria per cubic centimetre	46,000

Résumé.—In the preceding pages nine methods of sewage disposal or purification have been described, covering the most important methods in use at the present time. They include those methods by which sewage is purified by natural means—that is, by bacteria and air—and which have promise of such developments in the future as adequately to cover all sewage purification problems. The methods are as follows:

1. Disposal by dilution.
2. Sewage farming or irrigation.
3. Filtration through intermittent sand filters.
4. Chemical precipitation, followed by filtration.
5. Mechanical straining, followed by filtration.
6. Filtration through gravel or other filters of coarse material, with forced aeration.
7. Contact filters.
8. Septic tank treatment, followed by filtration.
9. Intermittent continuous filtration.

Summarizing these methods, it can be said that disposal by dilution is extensively practised and entirely satisfactory at such places as those mentioned in the previous text.

Sewage farming is successful in many places, especially with a concentrated English or European sewage.

Filtration through intermittent filters of sand or other fine material is a process which is already extensively used and is certainly destined to be used very largely in the future wherever such filters can be built at a reasonable expense. They are entirely successful wherever used, if the material of which the beds are constructed is suitable, and if such beds are properly operated.

Where a large amount of sewage must be taken care of upon a small area, or where some clarification must be made before sewage is disposed of by dilution, chemical precipitation is of undoubted value and will be used for many years in meeting such problems.

Straining sewage through coke or other materials of a like nature is undoubtedly successful on a small scale, and the future will show whether it can be applied to larger problems.

Forced aeration and filtration through gravel is hardly entitled to serious consideration in this connection, but as it was really the first step in the various processes of rapid filtration, it has been included in the previous text. It can undoubtedly be made practical and of use where the volume of sewage to be purified is small, and where cost is a secondary consideration.

The use of contact filters will increase undoubtedly at places where sand filters cannot be easily or inexpensively constructed. If they are properly built and properly operated, good results can be obtained by their use.

Septic tank treatment is also a proved success in some cases, and will undoubtedly be used much in the future. It must never be considered, however, as it is sometimes now considered by those ignorant of the subject, that the septic tank treatment is a purification. It is simply a clarification, and a preliminary treatment whereby sludge may be destroyed and the sewage may be so changed that either purification is made more easy by subsequent filtration, or the rate of filtration made greater than could be secured without this treatment.

Intermittent continuous filters seem to have very much of promise in them, and they will undoubtedly be adopted more and more at places where sewage must be disposed of upon a small area and where the climate does not interfere with their efficient operation. *H. W. Clark.*

SEX.—In the life history of nearly every multicellular organism there is a time when a new germ (oöspermium, or *zygote*) is formed by the union of two cells (*gametes*) of different aspect. The larger, less mobile of the two cells, is the *macrogamete*, egg, or ovum (*q.v.*), and the smaller more active one is the *microgamete*, spermatozoon (*q.v.*) or its equivalent. The ability to produce a macro- or microgamete constitutes the essential distinction of *sex*. The individual which produces the latter is said to be of the *male* sex, the individual producing the former is said to be of the *female* sex. In most of the higher plants and in a few of the lower animals both sexes are included in a single individual, which is then said to be *hermaphrodite*. The union of dissimilar gametes is the essential feature of sexual reproduction (see *Impregnation*). In many of the unicellular animals, Protozoa, there is a temporary union, or *conjugation*, of similar gametes, during which there is an interchange of part of the nuclear substance. In other Protozoa the gametes are of different size and the union is complete and permanent. Thus in these lowly forms we see foreshadowed the sexual process of the higher organisms.

If our definition of sex be correct, it follows that the quality of sex cannot be an attribute of the gametes, but only of the parent organism, except in so far as the sex of the offspring may be determined by some characteristic of one or both of the gametes. This view is borne out by what is known of the history of the germ cells, which has been shown elsewhere to be identical in all essential features in the two sexes (see *Reduction Division*). The differences between the gametes of the male and those of the female are confined to the cytoplasmic structures, and are associated with a physiological division of labor; the cytoplasm of the egg being more or less laden with food yolk and unprovided with locomotor apparatus, while the spermatozoon has practically all of its cytoplasm modified into a locomotor apparatus, by means of which it may actively seek the egg. This explanation is not in accordance, however, with the views of Geddes and Thomson, who see in the visible difference between egg and sperm evidence of the same differentiation of sex that is found in the adult. They regard sex as a quality of protoplasm. It is for them a question of metabolism. In the female the anabolic processes are predominant, while the katabolic processes are predominant in the male. These characteristics are passed on to the eggs and spermatozoa respectively, and fertilization "restores the normal balance and rhythm of cellular life."

It is difficult to follow the physiology of this conception of sex, for, if the male is predominantly katabolic, one would think it might be hard for him to grow; one might almost expect him to shrink. Havelock Ellis (1894) has gathered the published data in regard to the differences in metabolism of men and women, and he finds differences in certain phases, but the general result is inconclusive. Thus, men have a larger percentage of hæmoglobin in the blood and greater lung capacity in proportion to stature; but, on the other hand, women have a higher pulse rate. It is very probable that in the period of early maturity in women there is less katabolic activity than in men as is shown by the greater tendency to store up fat. But, if the words mean anything, a predominant condition of katabolism is inconsistent with increase of weight or with life itself beyond a very limited period, and therefore can hardly be accepted as the essential feature of "maleness."

We may follow Ellis in dividing the characteristics that distinguish the sexes into primary, secondary, and tertiary. The primary characteristics are those associated with the organs concerned in the production and union of the gametes. And these organs may be divided again into the essential and the accessory reproductive organs. The former are the gonads, called ovary and testis in female and male animals respectively. In low

forms, like the jelly-fishes, there are no other reproductive organs. But we need to go very little higher in the scale to find developed accessory organs that assist in the discharge and union of the gametes. Such are the oviducts, the vasa deferentia, and the appendages of these organs. Morphologically these tubes may be modified nephridea, or they may be newly developed structures. In all strictly terrestrial animals and in many of the higher groups of aquatic forms fertilization takes place within the oviduct. This is associated with a marked structural differentiation of the sexes. The male is usually provided with a special organ for the introduction of the spermatozoa. This may be a prolongation of the sexual orifice, forming a penis, or, as in the rays and higher crustacea, it may be in part a modified limb. In the female, on the other hand, the oviduct is either provided with glands to secrete a protective covering for the egg, or is modified to shelter the developing embryo, or even, as in the placental mammals, to nourish it during its fœtal life.

The secondary sexual characters are those that clearly distinguish the sexes without being directly concerned in the reproductive function. Among these characters we may distinguish clasping organs, weapons, ornamentation, voice, and appliances for the shelter or nutrition of the offspring. In a large number of animals, especially among the crustacea and insects, there are to be found special modifications of one or more limbs of the males which serve to hold the female in firm embrace during coitus. Many males are provided with weapons, as tusks, horns, spurs, or the like, which are employed in fighting with other males for the possession of the females. Often the males alone are provided with such weapons, and when they are possessed by both sexes, they may differ in the two sexes. Thus the cow has long, pointed horns adapted for defense against carnivorous enemies, while the bull has shorter, thicker horns, probably more useful for fighting with rivals.

In some cases structures that probably arose as weapons are now developed as ornaments. The most notable examples of this are the antlers of the deer family. In most cases, however, the ornamentation has arisen independently of the weapons, and consists of the most varied forms of coloring and modification of structure. Ornamental secondary sexual characters are found widely distributed among the insects, amphibia, reptiles, birds, and mammals. They are especially conspicuous among the birds. They are usually possessed by the adult males only, and reach their highest state of perfection during the mating season. After this season the deer shed their antlers, and many male birds, like the bobolink, exchange their bright plumes for the sober protective coloring of the female. This exuberance of growth and coloring in the males, together with the song of male birds, and other instances of greater activity, like the superior eagerness of the male in courtship, are taken by Geddes and Thomson as evidence for their conception of maleness as a preponderance of katabolic activity. But they leave out of consideration the fact that these conditions are not always characteristic of the male sex. In the species of phalarope—birds not uncommon on our shores—the female is the more brightly colored, the more pugnacious, and more ardent in courtship; in short, she has all characteristics usually found in a male, except that she lays eggs. The male, on the other hand, is relatively dull colored, is courted by the female, incubates the eggs, and takes entire care of the young.

The characters that we are considering are called ornamental, not because they appear beautiful to us—often they are quite the contrary—but because, according to Darwin's theory of sexual selection, they are supposed to have been developed through the choice, conscious or unconscious, of the courted sex (see *Evolution*).

In man we find ornamental secondary sexual characters in both sexes, which would seem to indicate that the courting is not all done by one sex. The chief of these characters in men is the beard. While women have longer hair on top of the head, and this is associated typically with an entire absence of visible hair on other parts of the body, except on the axilla and pubes. The layer of subcutaneous fat that develops in young women upon reaching maturity, and gives them the characteristic rounded contours of that period, may have become a fixed character of the species by the action of natural selection, owing to its value as a provision for the nutrition of prospective offspring; but, at any rate, it now forms one of the chief ornaments of women.

Sexual differences in the voice or in the method of using it are common, as every one knows, in amphibia, birds, and mammals. Witness the piping of the frogs, the song of birds, and the deep voice of men. Usually the modification of the voice is found in the males, and first appears, as in man, at the beginning of maturity. In fact, it is a general rule that when the male possesses special weapons, ornaments, or peculiarities of voice, these characteristics are not developed until about the time of the first ripening of the spermatozoa, and the immature males resemble the females. For this reason it has been inferred that the female, at least so far as these characters are concerned, represents a more primitive type than the adult male.

Devices for sheltering eggs or young are developed after different patterns in various groups of the animal kingdom, and they are usually confined to the females. Thus in most species of crustacea the female is provided with some means of carrying the eggs until they hatch. The female marsupials have a fold of the skin forming a pouch, in which the imperfectly developed young are placed at birth and are carried there until they are able to run about. The most characteristic organs of the mammalia and the ones from which the group has received its name, the mammæ, or milk glands, are possessed by the females of all species from monotremes to man. While functional only in the females, these organs are present in a rudimentary condition in the males also. Their importance as a means of rearing the young is so great that it has been questioned as to whether they should not be regarded as primary rather than secondary sexual organs. That they are essentially secondary, however, is shown by the practices of civilized women, who have largely relegated them to the position of ornaments—to the detriment of the best races of the human species.

In addition to the well-marked secondary sexual characters that distinguish males and females, there are other usually slight differences that Ellis classifies as tertiary sexual characters. We know very little in regard to these differences in the sexes of the other animals, but, thanks to Ellis, we have in his book, "Man and Woman" (1894), a very interesting and complete summary of these characters, anatomical, physiological, and psychical, in men and women. It would be impossible to summarize even his summary in the limits of this article. We can notice only a few of his conclusions and must refer the reader to the book for more.

Among the anatomical differences women show a greater youthfulness of physical type, as is common among females generally; but they show another anatomical peculiarity not found in other female mammals, and that is an enlargement of the pelvis. This, in the higher races of men, might be regarded as a secondary sexual character. A study of the brain and of the intellectual process in men and women gives the impression that the observed intellectual differences may be as much due to differences of training as to any innate differences between the sexes. In their senses women appear to be less discriminating, but more irritable, and in their emotions they show a greater affectability. Ellis thinks that women are more variable than men, but that this is true for all characters is denied by Pearson.

It is a general rule that in most species the two sexes are approximately equal in number of individuals, but in a few forms in which parthenogenesis is common there may be a large preponderance of females. From the records of 59,350,000 births in European countries Oesterlen (1874) calculated that the normal proportion of boys to girls is 106.3 to 100, and in the single countries the proportion of boys varied only between 105.2 and 107.2

The following statistics of the numerical proportion of the sexes in other animals were collected by Darwin ("Descent of Man," Amer. ed., vol. i., pp. 293-307):

	Number of cases.	Proportion of males to 100 females.
English race-horses	25,560	99.7
Greyhounds	6,878	110.1
English and Scotch sheep	59,650	97.7
Cattle	982	94.4
Fowls (pure Cochins)	1,001	94.7
Lepidoptera, various species	1,695	122.7

These figures are all taken from records of births except in the case of the sheep, in which the sex was recorded at the time of castration, and in the case of the lepidoptera, in which the sex of the imagos was recorded after emergence from the chrysalis. In the pigeons, which have two young in a brood, there is usually one of each sex, but occasionally both will be males, more rarely both females.

The question as to the factors that determine whether any given individual shall be a male or a female has excited the greatest interest since early times, and it is probable that there is no subject within the domain of biology on which so much nonsense has been written. According to Beard, it has been estimated that there are over five hundred theories, or rather hypotheses, of sex; and still we know practically nothing as to the cause of the determination of sex in the individual. It is manifestly impossible to review any considerable number of these hypotheses within the limits of the present article, and we will confine our attention to a few that deserve special attention because they are either very recent or are founded on experimental evidence.

Waldeyer (1903) divides the hypotheses into three groups which he calls progamous, syngamous, and epigamous. 1. According to the progamous theories the sex of the future individual is determined before the fertilization of the egg from which it is to develop. (*a*) According to some authors the differentiation takes place in the spermatozoon, (*b*) while others think that it is in the unfertilized egg that this occurs. 2. The syngamous theories hold that the sex of the embyro is determined at the time of fertilization, while (3) the supporters of the epigamous theories hold that the zygote and the embryo in its early stages are sexually indifferent, and that the sex is determined by external factors acting upon the embryo during its development.

There is evidence for the progamous determination of sex in the fact that some animals like the rotifer, Hydatina; the worm, Dinophilus; and the plant louse, Philloxera, produce two forms of eggs, the larger of which always develop into females, and the smaller into males. In Dinophilus the eggs are fertilized, but in the other two they are parthenogenetic, and thus in them there can be no question of the influence of spermatozoa. Each female of Hydatina lays normally but one kind of egg, and Nussbaum has shown that if females are well fed from the time of hatching they will produce exclusively female eggs; if poorly fed, male eggs.

Beard (1902) has attempted to formulate a general theory of sex based on the idea of two kinds of eggs. He thinks that sex is determined in the oögonia or in the synapsis stage of the oöcytes (see *Reduction Division*), and denies that the spermatozoa have anything to do with the determination of sex. The basis for this view is chiefly his discovery that in very young embryos of the skate, *Raja batis*, the number of primary germ cells in females is double that in males. His argument, however, is far from clear, and is by no means convincing.

The contrary view, that it is the spermatozoon that determines sex, is expressed by McClung (1902). In certain insects there is found in the primary spermatocytes an accessory chromosome that behaves differently from the others during synapsis. It divides but once during the maturation divisions, and the halves are distributed to two of the spermatids only (x, Fig. 3941, in article *Reduction Division*). Thus there are formed two kinds of spermatozoa in equal numbers, and McClung suggests that the ones containing the accessory chromosome are male and the others female, the accessory chromosome not being found in female germ cells. While this hypothesis may apply to the insects in question, it is inapplicable to the forms already mentioned in which the spermatozoa can have no effect.

Allied to these theories is the view that the determination of sex is a phenomenon of heredity. This is not a new idea, but it has been brought out recently again by two authors.

Orschansky (1903) distinguishes two types of families —in one a majority of the children are male, in the other female; and he tries to show that the other characters of the parents, especially predisposition to disease, are distributed among the children in the same way that the sexual characters are. But his conclusions are not obtained by precise methods, although he deals with large numbers.

Castle (1903) attempts to explain the determination of sex on Mendel's theory of heredity (see *Reversion*). His argument is briefly this: (1) Sex is an attribute of every gamete, whether egg or spermatozoon, and is not controlled by environment. It is inherited according to Mendel's law. So the formula for the second generation should be $M+2MF+F$. (2) But we do not get hermaphrodites usually, nor do we get pure males or females. The characteristics of one sex are always latent in the other. So the actual formula is $M(F)+F(M)$. (3) To explain this it is necessary to assume that a gamete of one sex can unite in fertilization only with a gamete of the opposite sex. (4) But one sex must be dominant and the other recessive or we should get hermaphrodites. It cannot be that one sex is always dominant. So it is necessary to assume that "Dominance, in diœcious species, is possessed sometimes by the male character, sometimes by the female." In other words, it is assumed that some organisms are male and some are female, which is the fact that we were trying to explain,—a good example of circular reasoning, and one not likely to lead us to a definite conclusion.

The only experimental evidence of the syngamous determination of sex is furnished by the bee. As was first shown by Dzieron, whose conclusions have been fully confirmed by Weismann and Petrunkewitsch, the question as to whether a given egg shall develop into a male or a female is determined by its being unfertilized or fertilized. The fertilized eggs develop into females, the unfertilized into males; another case in which McClung's theory would not apply.

Among the theories of the syngamous determination of sex are to be placed those in regard to the effect of the relative age of the parents or of the gametes, the relative sexual vigor of the parents, etc. Statistics have been gathered to show the effect of these factors. But they show at most a slight change from the normal numerical proportion of the sexes, and O. Schultze (1902) concludes from a series of experiments on mice, extending over two years, that these factors have no effect in the determination of sex. Included in this group is also the once much-heralded theory of Schenk. He thought that the sex of the zygote depends on the relative vigor of the gametes, and sought to influence this by improving the metabolic condition of the mother. His results were obtained from experiments on two or three women only, too few to afford a basis for sound generalization.

There is considerable evidence for the epigamous determination of sex by the state of nutrition of the embryo or larva. One of the earliest experimenters in this field was Mrs. Mary Treat, of Philadelphia. She divided a brood of caterpillars into two lots, and during the period between the last moult and the pupa stage one lot was well fed and the other was kept on the lowest possible diet. When the imagos emerged she found in the starved lot seventy-six males and three females, while the well-fed lot produced four males and sixty-eight females. These results were confirmed by Landois, who experimented on a thousand caterpillars of Vanessa; but doubt has been thrown on these results by Poulton, who finds that starvation produces a much higher death rate among females than among males.

Similar conclusions to those of Mrs. Treat and Landois were obtained by Yung from experiments on tadpoles. He found that normally about fifty-seven per cent. of the tadpoles developed into females. By feeding one lot with beef he raised the percentage to seventy-eight; by feeding a second lot with fish he raised the percentage still higher to eighty-one per cent.; and by feeding with the flesh of frogs he obtained as many as ninety-two per cent. of females. But these experiments, like the others, have been criticised by Pflüger and other writers as being inexact, possible factors beside nutrition having been neglected.

However, in the fresh-water polyp, Hydra, which is usually hermaphrodite, Nussbaum found that by good feeding he could stimulate the exclusive production of ovaries, and that in the ponds in the fall, when the food is becoming less, he found a greater number of males. Moreover, we know that in the plant lice sex is correlated with the condition of the food supply.

There are a good many experiments to show that in the lower plants sex may be regulated by food in the same way. On the other hand, Strasburger holds that it is impossible to influence the sex of diœcious phanerogams after the seed is formed from which the plant is to develop.

Whatever are the influences that determine sex they act primarily upon the essential reproductive organs, which in turn form the necessary condition for the development of the secondary sexual characters, as is shown by the effect of castration. If the gonads are removed before maturity the appropriate secondary sexual characters fail to develop, as in the familiar cases of horses, oxen, and capons. Moreover, diseases or removal of these organs after maturity affect the structure of the secondary sexual characters. Castration is employed sometimes by surgeons to reduce an hypertrophied prostate, and in women and in hens disease or removal of the ovaries has been observed to induce a partial development of latent male characters. How the gonads influence the rest of the body is not known, but from analogy with the thyroid gland, it is supposed to be by means of an internal secretion.

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SEXUAL ORGANS, FEMALE.—The female organs of generation comprise the two genital glands or ovaries that produce the sexual elements, the two oviducts that convey them, the single uterus that protects them after impregnation, and the single vagina and vulva that serve as organs of copulation (see Fig. 4191).

Development.—Originally the male and female organs are indistinguishable, both being developed out of an undifferentiated form. In many lower vertebrates the genital gland, the oldest and primary organ, empties its products (ova, spermatozoa) directly into the peritoneal cavity, whence they pass out by means of openings in the belly wall called abdominal pores. In the next higher forms these become associated with other organs of elimination and removal. Tubular canals termed *nephridia* communicate with the peritoneal cavity by means of a funnel-shaped opening or *nephrostome*, each having also a side branch that envelops an arteriole, thus forming a glomerulus and becoming an excretory duct for urine. The nephridia are, originally, arranged metamerically and are therefore sometimes called segmental organs. This arrangement gradually disappears by the increase of the canals which come to be assembled in distinct organs, successively developed; the *pronephros*, or head kidney, very simple in structure, the only functional urinary organ in amphioxus, persisting throughout life in some fishes, but disappearing early in man, and the *mesonephros*, primitive kidney or Wolffian body (Caspar Friedrich Wolff, 1735-94), which appears behind the pronephros, and which likewise consists of a series of nephridial tubules to each of which a glomerulus is attached, and which open into a duct (segmental duct, Wolffian duct) that, in common with the intestine, discharges into the cloaca, a short receptacle for excreta just above the anus.

In some fishes and amphibians the Wolffian body remains throughout life

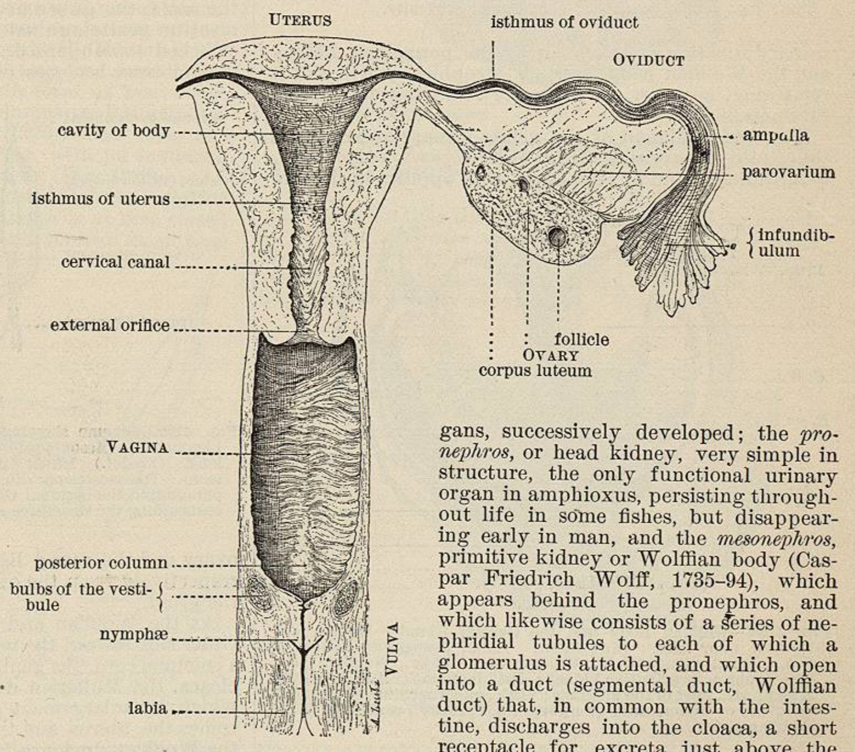

FIG. 4191.—Diagrammatic Frontal Section of the Female Genital Organs passing through the Orifice of the Vagina. The oviduct and the ovary are lifted up. (Henle, modified by Rieffel.)