RED BOILING SPRINGS.—Macon County, Tennessee. Post-Office.—Red Boiling Springs. Hotel.

Access.—Viâ Louisville and Nashville Railroad to Gallatin; thence by private conveyance to the springs.

This resort is located in the foothills of the Cumberland Mountains, sixty-five miles northeast of Nashville and seven miles from the Kentucky line. It has an elevation of about twelve hundred feet above the sea-level. The visitor will at this resort find a cool and pleasant retreat for the summer months. The hotel is said to be well kept and comfortable, and the cuisine of an excellent character. There are three springs in the group—two red sulphur springs and one black sulphur spring. Those most generally used are the "Little Red" and the "Black Sulphur" Springs. The former was analyzed by Lucius Pitkin, analytical and consulting chemist, of New York City, in 1890, with the following results:

Little Red Spring.—One United States gallon contains (solids): Sodium chloride, gr. 5.57; sodium sulphate, gr. 0.94; calcium sulphate, gr. 8.18; potassium sulphate, gr. 0.41; calcium bicarbonate, gr. 3.20; magnesium bicarbonate, gr. 4.55; iron bicarbonate, gr. 0.15; silica, gr. 0.80. Total, 23.80 grains.

Sulphureted hydrogen gas is present in large quantities.

The following analysis was made by James T. Anderson, of the Alabama State Agricultural and Mechanical College at Auburn:

Red Spring No. 2.—One United States gallon contains (solids): Sodium chloride, gr. 10.73; sodium carbonate, gr. 1.03; calcium carbonate, gr. 9.64; calcium sulphate, gr. 15.36; magnesium sulphate, gr. 7.97; alumina, gr. 0.12; iron oxide, gr. 0.08; silica, gr. 0.58; organic and volatile matter, gr. 2.31. Total, 47.82 grains. Sulphureted hydrogen gas is present in only small quantity. The temperatures of the waters are 54° and 52° F., respectively, and they do not vary during the year.

These waters are said to be actively diuretic, and to exert a general tonic and alterative effect upon the system. Hot and cold sulphur baths may also be had at all hours. A competent physician is always at hand to explain the proper use of the waters. *James K. Crook.*

REDLANDS AND RIVERSIDE, SOUTHERN CALIFORNIA.—These two places may be taken as representing the climate of the eastern foothills of Southern California, where are to be found many resorts favorable for a winter or an all-the-year-round residence.

Redlands (1,350 feet), in San Bernardino County, lies in the East San Bernardino valley, and is surrounded by mountains from 5,000 to 12,000 feet high on the north, east, and south, and lies open to the sea on the west, from which it is distant about eighty miles. The city is beautifully situated and substantially built, and contains about six thousand inhabitants. It is a favorite place of winter residence for Eastern people, and in attractiveness of situation and the character of its inhabitants and residences is comparable to Pasadena. Parks, many churches, a fine public library, excellent schools, clubs, golf links, good hotels, are all to be found here. The soil is porous and rich, and especially favorable for the cultivation of the orange, which is the principal fruit grown here. The water-supply is a fine one, and affords irrigation for the orange groves. There is a sewer and storm-water system, and the sanitary condition appears to be of the best.

Redlands has good railroad connections and electric roads; and from it one can easily reach the various attractive mountain resorts on the one side and those of the coast on the other.

One rarely meets with a more attractive town, even in Southern California, than Redlands, exhibiting as it does so many of the natural attractions peculiar to all this region. Wherever there is irrigation, flowers of endless variety abound, and the most luxuriant vegetation flourishes. The dust of the streets is laid by the crude petroleum, so abundant in Southern California. By this process an almost perfectly dustless road is obtained, and remains so for many weeks from a single application of the oil.

The characteristics of the climate of Redlands, as, indeed, of all this eastern foothill region, are equability, comparative dryness, abundant sunshine, and a small rainfall occurring mostly in the winter and spring. Early morning fogs, so-called "high fogs," may also be considered a climatic characteristic, for they are not of infrequent occurrence here, as elsewhere in Southern California.

The average rainfall is 15.59 inches, of which 7.45 inches falls in the spring and 6.55 in the winter. The mean annual relative humidity as given by Bridge ("The Climate of Southern California," Transactions of the American Climatological Association, 1901) is 64.4 per cent. The average mean winter temperature as given by the same authority is 54.7°; for summer, 75.3°; spring, 63°; autumn, 66° F. (Solly). Sanborn ("The Climate of the Eastern Foothills," by Dr. C. A. Sanborn, Redlands, Cal., Transactions of the American Climatological Association, 1902) gives for Redlands the following extremes of temperature from an average of three years for the three months exhibiting the greatest extremes of heat and cold:

January	Mean maximum temperature	 62	degrees.
	Mean minimum "	 40	"
February	Mean maximum "	... about 69	"
	Mean minimum "	 42	"
July	Mean maximum "	... about 95	"
	Mean minimum "	 59	"
August	Mean maximum "	... about 91	"
	Mean minimum "	 58	"

The average mean relative humidity of Redlands for these months is given by the same authority as 55.7 per cent.

In the summer the temperature occasionally goes above 100° F. in the middle of the day, but with the dry atmosphere this is not so uncomfortable as might be supposed. The difference between the day and night temperatures is great, something like 20° to 30°. Similarly, there is a great difference between the night humidity and the day humidity. "This means to an invalid," as Solly remarks ("Medical Climatology"), "a climate possessing, in the course of the day, perhaps six hours of moderate dryness, and eighteen hours of positive dampness."

These two characteristics of the fall in temperature and increase in dampness at night probably account for the apparent chariness with which the residents open and keep open their windows, and the fear they have of sitting out of doors at night. As paradoxical as it may seem, one can evidently sit out of doors more evenings in the year in New England than in Southern California; or else the New Englander is more venturesome and hardened in enduring the evening air than is the Californian of the South.

Freezing weather is very rare.

The mountains to the north of this valley shut off the winds from the desert, but the sea breeze blows daily, beginning usually about ten o'clock in the forenoon, and lasts until sunset. There are said to be over three hundred sunshiny days in the year at Redlands. At San Bernardino, about eight miles to the northwest, the total number of clear days, as given by Dr. A. K. Johnson, a volunteer observer (period not given), is 235; fair days, 95; cloudy, 35; rainy, 33½. According to Sanborn (*loc. cit.*) "patients with pulmonary lesions, not far advanced, do well in this climate (Redlands and vicinity), especially in that part of the valley where orange growing and the consequent dampness from irrigation do not prevail." Sanborn also refers to the irritation of the respiratory tract brought about by the extensive use of commercial fertilizers. He has noticed a prevalence of tonsillitis and pharyngitis occurring at the time of using this material. "Nervousness" is said to be increasing here as well as in other portions of Southern California, and it is attributed by Sanborn to various causes, climatic and others, such as eye strain from a succession of bright days, and nostalgia.

Five miles from Redlands, on the line of the Southern

Pacific Railroad, is the *Loma Linda Sanatorium* (about twelve hundred feet), beautifully situated on the hillside about two hundred feet above the surrounding country. It is approached through a stately avenue of pepper trees, and is surrounded by orange groves and beautiful gardens. The view from the sanatorium is extensive and grand, the lofty "Arrowhead" and its hot springs lying directly in front. The buildings of this institution are well equipped, containing operating-rooms, etc., and excellent accommodations are offered to the nervous and other invalids, as well as to those who only desire to rest under such favorable conditions of situation and climate. The tuberculous are not received here.

Riverside (elevation eight hundred and fifty feet) is a city of ten thousand inhabitants, about sixteen miles by rail southwest from Redlands. It is the most famous orange-growing district in Southern California, and is well supplied with water for irrigation and domestic purposes, from a number of artesian wells near the mountains. The drainage is good, and the city affords every opportunity for comfortable living, either for the transient or for the permanent resident. There are attractive parks, in one of which is the curious "cacti garden." There are also beautiful estates, many churches, fine school buildings, a Carnegie library, miles of pleasant roads through the orange groves, and avenues shaded by the eucalyptus, the pepper, and the palm, among them the famous Magnolia Avenue.

The vegetation, as at Redlands, is most luxuriant, and besides the orange, the pomegranate, olive, persimmon, fig, and other fruits are found here. Flowers abound in a wild profusion, and this whole area seems like one vast park or garden.

The accommodations are good. Besides the lovely drives and walks, there are opportunities for golf, polo, and tennis.

The climate is similar to that of Redlands. The average yearly rainfall for fourteen years was ten inches, February and March being the rainiest months (Solly, "Medical Climatology"). The relative humidity for the year 1888 was 65.5 per cent. The mean monthly temperature for the seasons, covering a period of twelve years is as follows: Spring, 60°; summer, 74°; autumn, 74°; winter, 51° F.* The mean for July is 76°; maximum, 106°; mean for August, 76°; maximum, 104°; mean for January, 50°; minimum, 29°. The average variation between the day and night temperatures, as given by Sawyer ("A Study of Riverside Climate," etc., Southern California *Practitioner*, 1887), for January is 20°, and for July, 34°. "The ordinary wet season at Riverside," says the same author, "is much drier, has less rain, and a larger proportion of dry, clear sunshiny days than the average summer in New York, Boston, or Chicago." The amount of sunshine is great, and, according to Sawyer, there were two hundred and eighty absolutely clear days from July, 1885, to July, 1886.

Thirty-five miles southeast of Colton, which is eight miles north of Riverside, is the little town of Hemet, the starting-point for the carriage ride to the health resort of *Idyllwild.* This is a journey of twenty miles, the last ten of which are up a steep mountain road. Idyllwild has an elevation of 5,250 feet, and is situated in the Strawberry Valley, in a large forest tract of fifteen hundred acres, which is again bounded by extensive government forest reservations. The valley is well timbered, the pine, cedar, and live oak predominating. The climate possesses the characteristics of the high altitudes in a comparatively warm latitude, the atmosphere being dry and pure; and the temperature warm but not hot in summer, and in winter cool, but not generally going below the freezing point. As is generally true of this whole region the majority of the days are sunny.

The Idyllwild Sanatorium occupies a well-protected situation, and besides a large, well-appointed central building containing fifty-one rooms, there are several cottages of three and six rooms, tents, etc. There are appliances for furnishing steam heat and electricity, an ice plant, and a steam laundry. Families who come with their invalids can also find accommodations here, and means of recreation in riding, golf, tennis, etc. There is also a school for the younger children. The sanitary conditions are well looked after. The water comes from a pure mountain spring, and there is a well-constructed sewer system. The plumbing is modern and good.

Pulmonary tuberculosis in the curable stages is the principal disease treated here, and there are a resident physician and nurses.

From a personal visit the writer can testify to the wild beauty of the scenery, the delicious purity of the air, and the energy and devotion of the managers in building on this mountain plateau a well-equipped and extensive sanatorium, with all modern improvements. For one who desires to take the open-air treatment in the high altitudes, and at the same time avoid the severity of the winter climate found in the altitudes farther north, such as at Colorado and in the Alpine resorts of Europe, Idyllwild would seem to afford ideal conditions, not only of climate, but of accommodations. The only drawback is the long, tiresome carriage ride, but this in time will probably be obviated by a mountain railway.

Edward O. Otis.

* Quoted by Solly from a meteorological record issued by the Riverside Board of Trade.

RED SULPHUR SPRINGS.—Monroe County, West Virginia. Post-Office.—Red Sulphur Springs. Hotel.

Access.—Viâ Chesapeake and Ohio Railroad to Alderson's, thence by stage to springs.

These springs are beautifully situated on Indian Creek, and are surrounded by pine-clad mountains. They are two in number, and flow two hundred and ten gallons per hour. The water has a temperature of 51° F. It was analyzed in 1842, but the results were not very satisfactory. The total solids found to be present in one United States gallon amounted to about twenty-four grains, and approximately one-third of this consisted of sulphur.

A new analysis of this water is very much to be desired. Its virtues are presumed to rest to a great extent upon the sulphur which it contains. Aside from this substance it contains ingredients which justify us in classing it as a light saline calcic water. From abundant corroborative medical testimony there seems to be no doubt that the water causes a decided slowing of the heart's action in an excited state of the circulation. The water further seems to exert a soothing influence upon the mucous membrane of the lungs and bronchi, allaying irritation and diminishing expectoration. In virtue of these properties it has often proved decidedly beneficial in hæmoptysis, early phthisis, chronic bronchitis, chronic pharyngitis, and chronic laryngitis. In small quantities the water is said to be cathartic, while in larger doses it is diuretic. *James K. Crook.*

REDUCTION-DIVISION.—When in the course of cell division the chromatin is distributed to the daughter nuclei in such a way that the material forming one daughter nucleus has a different ancestral history from the material forming the other, the division is called a reduction, or, better, *reducing division*; and is thus distinguished from the ordinary *equal division*, in which every particle of the chromatin is divided equally between the two daughter nuclei (see article *Cell*).

Theoretical.—If we suppose that the physical basis of heredity consists of distinct units in the chromatin material of the nuclei of the germ cells, then at each union of two germ cells in sexual reproduction the number of ancestral units, or ancestral germ-plasms, will be doubled. And, unless prevented in some way, this doubling will continue with each successive sexual union, until either the germ cells will be increased to an enormous size, or else the units will be reduced in size so much that they are smaller than the proteid molecule.

Roux in 1884 published an elaborate review of the whole subject of mitotic cell division, so far as it had been developed at that time, and his conclusion was that the *longitudinal splitting* of the chromosomes and the whole mechanism by which the two halves of an originally single chromosome are always carried to opposite poles of the spindle, has for its object the distribution of the chromatin, both as to quantity and as to quality, in exactly equal proportions to the two daughter cells (see *Chromosome*).

A study of the phenomena of heredity led Weismann to suppose the chromatin to be made up of elements as indicated in the previous paragraph (see also article *Heredity*) and that these ancestral germ-plasms maintain their individuality through successive generations. And this led to the further supposition that sexual reproduction can be continued only in case there is a reduction in the number of ancestral germ plasms, a reduction that must be repeated in every generation. But Roux's conclusions would seem to make such a reduction improbable so long as the division takes place by the ordinary method accompanied by a longitudinal splitting of the chromosomes.

Writing in 1887, Weismann says: "This is the only kind of karyokinesis which has been observed until recently; but if the supposed nuclear division leading to a reduction in the number of ancestral germ-plasms has any real existence, there must be yet another kind of karyokinesis in which the primary equatorial loops are not split longitudinally, but are separated without division into two groups, each of which forms one of the two daughter nuclei. In such a case the required reduction in the number of ancestral germ-plasms would take place, for each daughter nucleus would receive only half the number which was contained in the mother nucleus." After discussing the work of van Beneden (1883) and Carnoy (1886), then recently published, Weismann defines the terms "reducing division" and "equal division," and then adds the following explanation of his prediction: "The 'reducing division' must be always accompanied by a reduction of the loops to half their original number, or by a transverse division of the loops (if such division ever occurs); although reduction can only occur when the loops are not made up of identical pairs. And it will not always be easy to decide whether this is the case. On the other hand, the form of karyokinesis to which a longitudinal splitting of the loops takes place *before* they

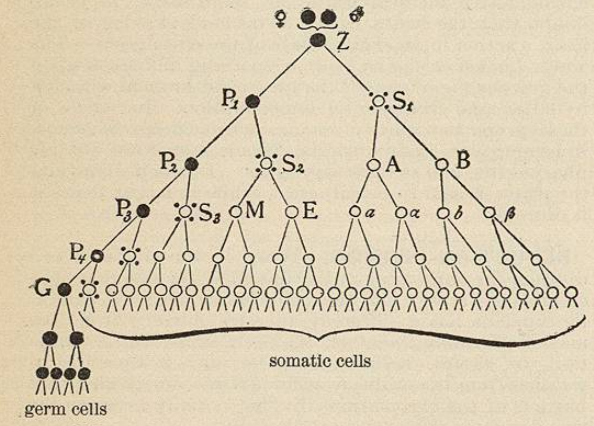

FIG. 3926. — Diagram showing the Pedigree of the Germ Cells of Ascaris. *Z*, Fertilized egg; P_1, P_2, etc., protogonocytes; *G*, primordial germ cell (P_5, Fig. 2614, article *Heredity*); S_1,S_2, etc., primary somatic cells; *A* and *B*, primary ectodermal cells; *E*, primary endodermal cell; *M*, cell which produces mesoderm and part of ectoderm. (Modified from Boveri.)

separate to form the daughter nuclei must always, as far as I can see, be considered as an 'equal division.'"

This prophecy is one of the most famous in the annals of science, because it has been one of those most fertile of results, having furnished the stimulus for a large number of very careful investigations. It is the purpose of the present article to describe some of these results, and to consider whether they show a fulfilment of this prediction.

The Germinal Cycle.—The complete history of the germ cells has not yet been followed through all its stages in any animal or plant. But enough is known to make it

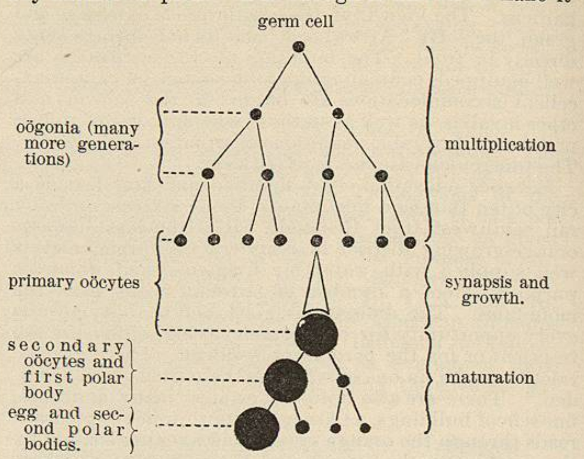

FIG. 3927.—Diagram showing the Genesis of the Egg. (Modified from Boveri.)

clear that there is a complete continuity of generations of cells in this history, which consists of a series of cycles, and we may consider each cycle as having its beginning and its end in the act of fertilization. These cycles follow one another in unending sequence so long as the race remains extant.

The *germ cells* are those which have for their purpose the provision of the material out of which future generations are to be produced, and they form but a small portion of the body of any multicellular organism. The greater part of the body is made up of *somatic cells*, which serve to shelter and nourish the germ cells. The history of the somatic cells is likewise a series of cycles having their beginnings in the act of fertilization. But there is no continuity between the cycles. For the somatic cells, having fulfilled the purpose of their being, die, and have no genetic relation to the cells forming the body of the next generation, except community of origin in the ancestral germ cells.

In the history of the germ cells each cycle may be divided into several periods, and the cells in each period have been given distinctive names. We shall follow in the main the terminology recently adopted by Waldeyer (1902).

By the union of an ovum and a spermatozoon there is formed a single cell with a nucleus of double origin (see *Impregnation*). This cell is the fertilized egg, or *oösper-mium*. Immediately after fertilization there follows a series of cell divisions resulting in what is known as the segmentation of the ovum (see article *Segmentation of the Ovum*). The result of the first division is the formation of two cells—the first primary somatic cell and the first stem cell, or *protogonocyte* (S_1 and P_1, Fig. 3926). The latter divides again to form a second primary somatic cell and the second protogonocyte (S_2 and P_2). This series of divisions continues through a series of generations of cells, the number of which varies with the species (see *Heredity*), until finally the last protogonocyte gives rise to a primary somatic cell and the primary germ cell or *archigonocyte* (S_5 and *G*, Fig. 3926). In the mean time, of course, the somatic cells have been dividing to form the tissues of the embryo.

The second period begins with the division of the archigonocyte to form two *gonocytes*. These continue to multiply by division until, according to Beard, they reach a certain number, which may be approximately constant for the species. Finally, whether by migration or otherwise, the gonocytes come to lie in the germinal epithelium upon the genital ridge. (For the sake of clearness we

will confine our attention to the higher animals for the present.)

The beginning of the third period coincides with the differentiation of the genital ridge into ovary or testis, and in this period the history of the germ cells begins to diverge in the two sexes. In the female the last generation of the gonocytes may produce two kinds of cells. Some produce follicle cells or other cells serving to nourish the eggs, while others give rise to the first generation of *oögonia*, or primordial eggs. The oögonia continue to multiply for an undetermined number of generations. Finally this period of multiplication is followed by a period of growth during which division ceases. The oögonia have now become *primary* oöcytes (see Fig. 3927).

The period of growth is followed by the period of maturation, during which two cell divisions occur, usually in rapid succession. The primary oöcyte, having attained its full size, divides very unequally to form the *secondary* oöcyte and the first polar body. Then the oöcyte divides again unequally, forming the second polar body and the ripe ovum, or *ovium* (Greek ὠϊον, egg), as Waldeyer prefers to call it. The first polar body may divide also at the same time, so the maturation divisions result in the formation of four cells—the relatively large ripe egg and three very small polar bodies. The view now universally held, that the polar bodies are abortive eggs, was first stated by Mark in 1881.

These periods in the history of the egg are exactly parallel in the history of the spermatozoon. In the male the last generation of gonocytes may likewise give rise to nutritive cells and to *spermatogonia*. The latter multiply by division for an indefinite number of generations of cells and the last generation gives rise to primary *spermatocytes*, which then enter upon a period of growth (Fig. 3928). This is followed, as in the egg, by two maturation divisions. In the first the primary spermatocyte separates into two secondary spermatocytes, and by the second division each secondary spermatocyte produces two *spermatids*. Thus the maturation divisions result in the production of four cells, but in the male these are all of the same size and all are capable of becoming functional.

But in order to become functional the cell must pass through another period, not represented in the history of the egg. This is the period of histogenesis, during which

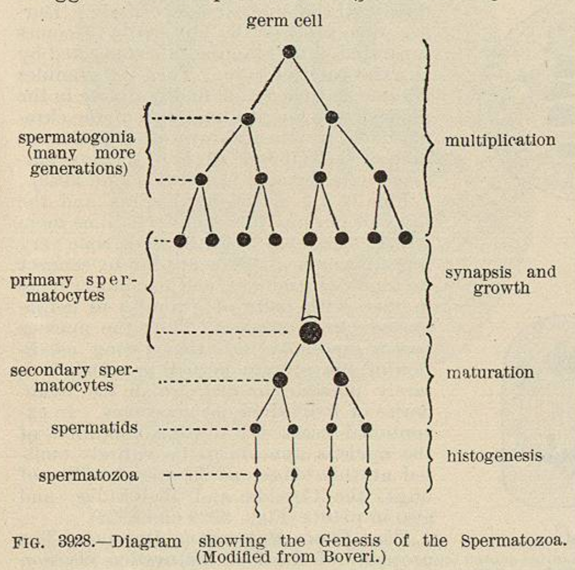

FIG. 3928.—Diagram showing the Genesis of the Spermatozoa. (Modified from Boveri.)

the spermatid undergoes a remarkable metamorphosis by which it becomes transformed into a *spermatozoon* with the characteristics peculiar to its species (see article *Spermatozoa*). With the entrance of the spermatozoon into the egg and the union of the sperm nucleus with the egg nucleus the old cycle ends and a new one begins.

During the periods from the first cleavage of the ovum to the last division of the oögonia or spermatogonia the number of chromosomes present during the prophases of division is always the same in individuals of the same species and is, with rare exceptions, the same as the number found in the somatic cells (Figs. 3936, 3937, and 3929, *B*). But at the beginning of the growth period the nuclei of the germ cells undergo a remarkable series of transformations, which result in the reduction of the number of chromosomes to one-half the number present in the earlier periods; and the reduced number is found in the oöcytes, spermatocytes, and spermatids, and in the egg and sperm nuclei previous to their union. (Compare the figures cited above with Figs. 3938, 3940, and 3929 *L*.)

Therefore, if a reducing division, as defined by Weismann, really occurs, it is to be sought for in one of the two divisions immediately following the growth period. These are the maturation divisions.

In considering the results of investigations upon this subject, the reader should bear in mind that before the material can be studied it must be killed, hardened, embedded in paraffin, cut into sections, stained, and mounted in balsam; and that each one of these operations is a possible source of error. Moreover, the objects are so minute that they can be studied only with the aid of a microscope of high magnifying power, and, further, it is impossible to view any one of these objects from more than one side. It is doubtless due to these difficulties of observation that the published descriptions of what takes place during this most interesting and important period in the history of the germ cells are so diverse and so often contradict one another. Although much has been written on the subject, the diversity of results is so confusing that it is impossible to formulate any general description that will apply to all species. Nevertheless there is sufficient agreement to encourage the hope that the progress in the improvement of methods will eventually lead to such a uniformity of results as to make it possible to formulate a general law applicable alike to all species of animals and plants.

At present the most complete and consistent account is to be found in a series of papers by Montgomery, who has studied the spermatogenesis in forty-two species of bugs, hemiptera heteroptera, and in Peripatus, a form of special interest on account of its supposed relation to the ancestral type of the insects and their allies. The following general description will be based, therefore, chiefly upon Montgomery's results, supplemented by the work of Paulmier upon spermatogenesis in the squash bug, *Anasa tristis* (Fig. 3929). The general account will be followed by sections, treating briefly of the parallel phenomena in oögenesis, and by others referring to variations to be found in other animals and in plants.

The Last Spermatogonic Division.—In the resting spermatogonia the chromatin appears to be scattered irregularly throughout the nucleus, but the granules are connected by the threads of linin. The nucleus is like a lacework ball made of strings of beads, in which the thread is the linin and beads the chromatin. In the early prophase of division the chromatin becomes arranged in a single long winding thread covering; according to Montgomery, a single strand of linin. This is the dense spireme stage. The spireme continues to shorten, and at the same time the chromatin becomes segmented into the number of chromosomes characteristic of the species. This number varies from eleven to twenty-eight in the bugs. But the linin remains intact and connects the chromosomes by their ends. The achromatic spindle is formed, the chromosomes are arranged in the equatorial plane, split longitudinally, and the halves are drawn to opposite poles in the typical manner.

In Peripatus the chromosomes are rod-shaped at this stage, and in the late anaphase they lie parallel to the spindle fibres. The ends pointing toward the centrosome are called the *central ends* and the opposite ones are the *distal ends.* The distal ends of sister chromosomes are joined by "connecting fibres" of linin, and although unable to prove it, Montgomery thinks that probably the linin in each daughter group of chromosomes still forms a continuous spireme, so that each chromosome is connected by it at the central end with its neighbor on one side, and at the distal end to the neighbor on the other side. Finally the chromosomes become massed in a dense group, but not fused, near each centrosome, and the cell body becomes constricted in the middle. The two daughter cells are primary spermatocytes.

Synapsis.—The young primary spermatocytes are easily distinguished from young spermatogonia by the peculiar condition of the nucleus. The changes which take place at this stage were first described by J. E. S. Moore in 1895, under the title *synapsis* (συνάπτω, to fuse together). And it now seems probable that the synapsis is a stage of universal occurrence in the history of the germ cells of both animals and plants. An especially characteristic feature of the synapsis is the grouping of the chromatin in a dense mass on one side of the nucleus, leaving a large clear space on the other side, between the chromatin and the nuclear membrane. (Compare Figs. 3929 *D* and *E*, 3933 *B*, 3934, and 3938.) The interest attached to this phase is due to the fact that when the chromatin emerges from this tangle it is found to be divided into segments of just *half* the number present in the previous anaphase, and these segments are either split longitudinally or soon after become split. It is at this time, then, that the *reduction* in the number of chromosomes takes place; and it would seem that this reduction without division, as has been held by Moore, Farmer, and others, destroys all ground for Weismann's theory of a reducing division.

In most forms the mass of chromatin during the synapsis is so dense that it is impossible to see what takes place within it. But in Peripatus Montgomery was so fortunate as to find a form in which it is possible to distinguish the individual chromosomes, and he was able to determine that they become *fused in pairs by their central ends*, and a similar result has been obtained by Sutton in the grasshopper (Fig. 3938). Thus if the twenty-eight chromosomes that enter the synapsis stage in Peripatus are univalent, the fourteen that emerge from it are bivalent, and no true reduction has taken place after all, for there has been no discharge of chromatin from the nucleus. The bivalent chromosomes have the form of the letter V or U, and the angle of the V or U marks the position of the central ends, which in some cases can be seen to be connected by a short band of linin.

On emerging from the synapsis stage the chromosomes gradually elongate, and finally fill the nuclear space again. During this process the chromatin becomes separated into granules, all connected by an axial band of linin. Then the granules become flattened and finally divide in the plane of the longitudinal axis of the chromosome, forming a row of granules on each of the opposite edges of the now flattened axial band (Figs. 3929 *F* and 3939).

Finally the axial band splits and the rows of chromatin granules become more widely separated. At the same time very fine filaments of linin appear to connect each pair of granules, and to connect there in turn with pairs of granules in neighboring chromosomes. Thus the nucleus passes gradually into the resting condition of the growth period, in which it is rarely possible to distinguish the boundaries of individual chromosomes. In exceptional cases the resting condition of the nucleus appears to be entirely omitted at this stage, as in two families of bugs, the Coreidæ and Reduvidiæ, and also in plants (Figs. 3929 and 3938).

The First Maturation Division.—The prophase of the first maturation division in Peripatus begins with the coming together of the chromatin granules to form an irregular reticulum. There is no spireme, but the reticulum appears to give rise to the chromosomes directly, and

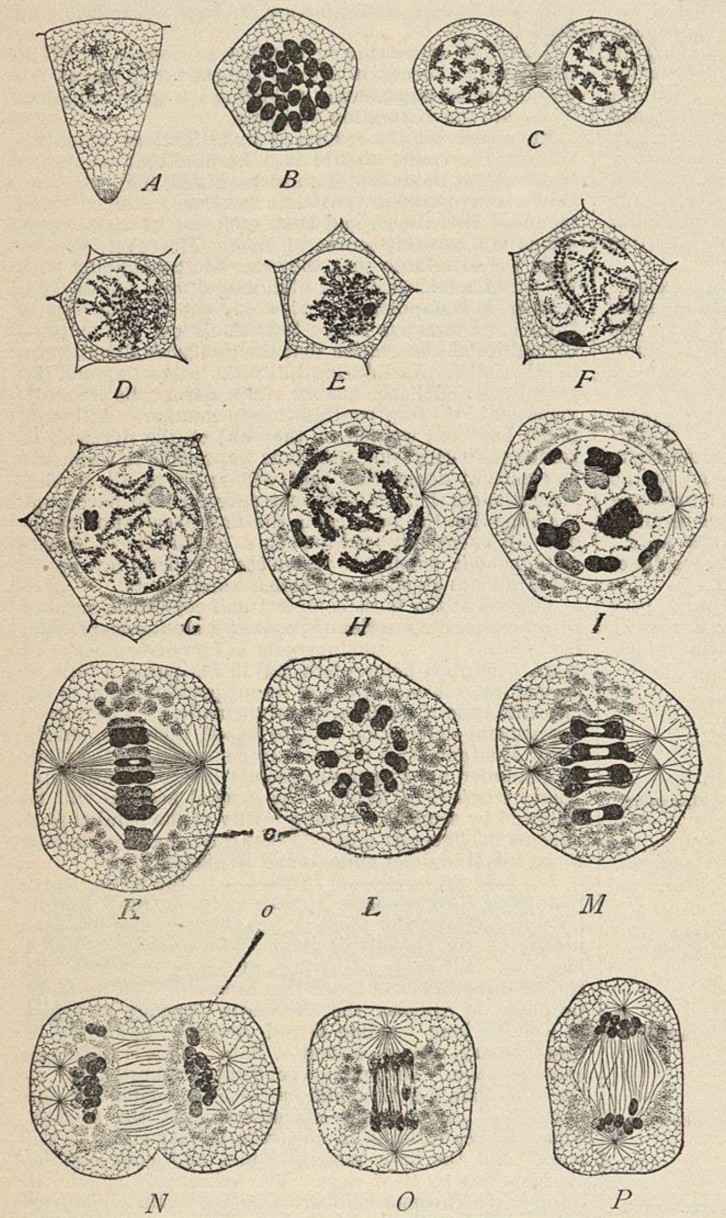

Fig. 3929.—Various Stages in Spermatogenesis from Sections of the Testes of the Squash Bug. *A*, Spermatogonium; *B*, spermatogonium preparing for division, cross section of equatorial plate showing twenty-two chromosomes; *C*, division of spermatogonium nearly completed; *D* and *E*, primary spermatocyte in synapsis; *F*, *G*, *H*, and *I*, stages in the formation of tetrads; *K*, *L*, *M*, and *N*, first division of spermatocyte; *O* and *P*, second division of spermatocyte; *o*, accessory chromosome. (From Wilson, after Paulmier.)

Montgomery gives reasons for believing that the reticulum is only apparent, and is really formed of overlapping and interlacing chromosomes that have never lost

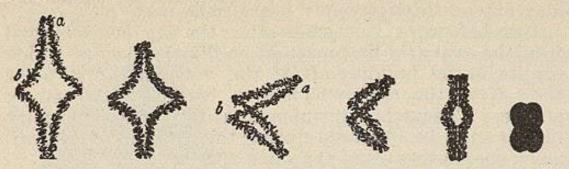

Fig. 3930.—Chromosomes from Primary Spermatocytes of the Squash Bug, showing changes of shape leading to the formation of tetrad. *a*, Distal end; *b*, central end; 6, completed tetrad with long axis corresponding to the longitudinal split. (After Paulmier.)

their identity. The chromosomes shorten and assume a great variety of form, most of them being more or less U- or V-shaped. Sometimes the two limbs of the U are twisted together, sometimes they are united at the ends to form a ring. These chromosomes are seen to be bivalent, that is, composed of two univalent chromosomes united by a band of linin at the bend of the U, and each univalent component is split longitudinally. The chromosomes which take part in the first maturation division are therefore similar in form as well as equal in number to those at the end of synapsis.

By the time that the chromosomes reach the equators of the spindle they have become very much condensed, so that the central linin band is covered with chromatin and the longitudinal split is represented by a mere notch at the distal end. In Peripatus the chromosomes at this stage most frequently have the form of a bent dumbbell,

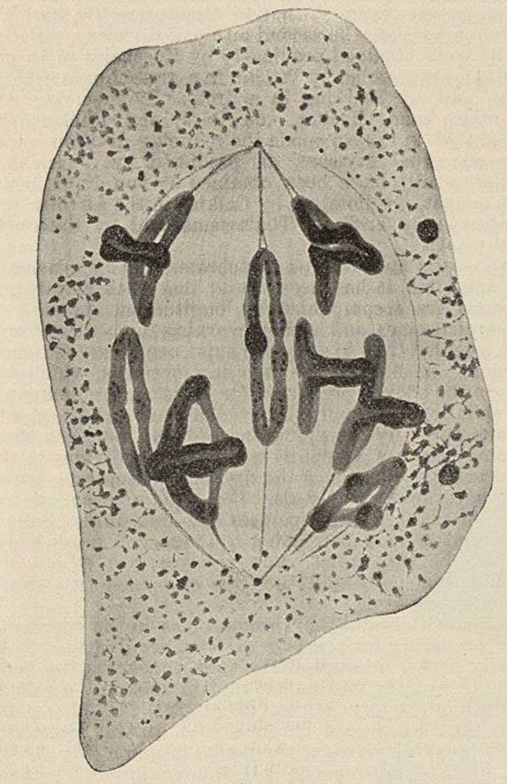
Fig. 3931.—Primary Spermatocyte of Batrachoseps in a Stage Immediately Preceding the Metaphase. Eight of the twelve chromosomes are seen approaching the equator of the spindle. × about 1,500. (After Eisen.)

sometimes it is a straight dumbbell, sometimes two thick parallel rods, and more rarely a ring-shaped chromosome is found. In many insects and crustacea the chromosomes at this stage have the form of *tetrads* (Fig. 3929 *K*); that is, each bivalent chromosome is seen to be composed of four minute balls of chromatin more or less closely pressed together. In vertebrates and in the higher plants the chromosomes are more or less ring-shaped at this stage (Fig. 3931).

The chromosomes now divide in a plane at right angles to the axis of the spindle, and the halves are drawn toward the opposite centrosomes. In the case of Peripatus the dumbbells are divided transversely. Where the tetrads are present, the daughter chromosomes are *dyads*, each composed of two balls of chromatin (*M* and *N*, Fig. 3929). The ringshaped chromosomes are broken so as to form two horseshoe-shaped bodies (Fig. 3932).

If this division of the bivalent chromosomes takes place in such a way that their original univalent components are separated, we have here a *reducing division*, as described by Weismann. But if the daughter chromosomes consist of parts of two originally separate chromosomes, then we shall have to seek farther for the reducing division.

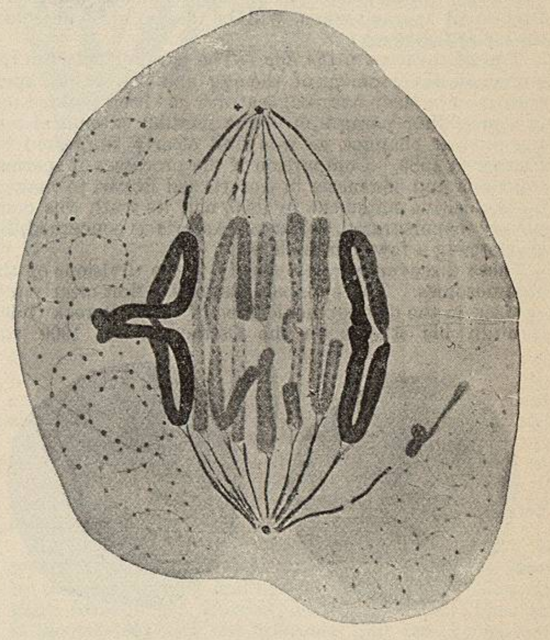
Fig. 3932.—Primary Spermatocyte of Batrachoseps in the Metaphase, Chromosomes Dividing. × about 1,500. (After Eisen.)

The question can be decided only by very careful study of the changes in form and structure exhibited by the chromosomes from the beginning of the synapsis to the completion of this division. This has been done by Paulmier in the case of the squash bug, and by Montgomery in forty-two Hemiptera and in Peripatus. They find that in all of these species the first maturation division is transverse, and is a *true reducing division*, separating each bivalent chromosome into its original components.

Both Montgomery and Paulmier figure each daughter chromosome as being drawn toward its respective centrosome by two spindle fibres (*K*, Fig. 3929). Soon each centrosome divides into two preparatory to the next cell division, and it is found in Euchistus and in the squash bug that of each pair of spindle fibres one is connected with one daughter centrosome, and the other fibre is attached to the other one (*M*, Fig. 3929). With the division of the cell bodies the first maturation division is completed, forming two *secondary spermatocytes.*

The Second Maturation Division.—Usually there is no resting condition of the nucleus between the first and second maturation divisions. The longitudinal split which appeared in the chromosomes during the prophase