IRISH LINEN.—II.

SOME FEATURES OF ITS PRODUCTION.

BY SIR WILLIAM CRAWFORD.

Concluded from Supplement No. 1796, page 363.

VERY considerable improvements have taken place in the spinning mills and weaving factories with regard to the conditions under which the operatives work. Chief among these is the diminution which has been effected in the amount of dust floating in the air of many of the rooms. In this improvement Mr. R. H. Reade, chairman of the York Street Flax Spinning Company, Limited, has been the pioneer. The first distinct step in clearing the dust out of the dusty rooms was to localize the exhaust, that is to say, to collect the dust as near as possible to the point at which it is produced, and the principle has been gradually applied, beginning with the worst places in the mill. The final result might almost be described as a revolution, so marked is the improvement in the atmosphere compared with what was looked upon as the normal and inevitable dusty condition of these rooms twenty years ago. In the wet spinning rooms, close attention to the design and condition of the trough lids, coupled with better covering of steam pipes and general exhaust ventilation, has greatly reduced the excessive heat and moisture of the rooms, and brought the last well within the limits imposed by the Home Office. In weaving sheds, the better distribution and more extensive application of ventilating and exhaust appliances to satisfy the standard of air purity required by the Home Office, has likewise improved the conditions there, though to a less marked degree than in the spinning. These changes have been introduced by the masters partly on their own initiative, and partly at the instigation of the Home Office inspectors, and have brought about a distinct and much-appreciated improvement in the health of the workers. Their trade unions have formally acknowledged the benefits they have derived.

Perhaps the improvements in the machines used in the flax industry have not been so rapid or so great as in some other textile industries. However, there have been some, and I may tell you of one that is now coming into extensive use in the hackling of flax. This invention, due to Mr. James G. Crawford, can be attached to the ordinary hackling machine. Formerly four boys were needed to attend to a pair of hackling machines, and the work devolving on each of the four boys was extremely arduous—so arduous that they remained at it only so long as they were unable to obtain work in another industry. By this invention one boy can attend to a pair of hackling machines instead of four boys, and the one boy's work is extremely light. It thus effects a saving of 75 per cent in wages, and in addition the work is better done, and practically all the boys can be retained and advanced to apprenticeship in one or other of the trades connected with the flax industry.

A recent action of the united body of flax spinners is, I think, worthy of being recorded to their credit. In 1908, during a period of unexampled dullness and depression, those masters, finding that, although they had for some months been running their mills two-thirds time in order to lessen production, their stocks continued to rise, resolved in June of that year still further to reduce production by five hours a week. At the same time, however, they agreed to make no further reduction in the wages of women and young people employed by them. And this payment of unearned wages for five hours a week continued for seven months, and constituted a gift of about \$150,000. I have never heard of a similar act elsewhere. In 1906-7 spinners' wages had been advanced by 20 per cent. Therefore a woman who before 1906 had been earning \$2.45 a week of 55 hours was temporarily, in the time of stress, paid \$1.96 per week of 32 hours.

We now come to the third division, viz., bleaching. In olden days that process could be carried through only in the long days between March and October, and it was produced by primitive methods, such as boiling the linen in lye made from burned seaweed, and then spreading it on the grass field exposed to the effects of sun, air, and rain, and artificial watering. After six months or so of this treatment, the linen was steeped in buttermilk, washed in pure water, and finished up. The color obtained by these methods was not so white as is now common, but the bleached linen retained a high proportion of its natural strength. With steam-driven spinning machinery there ensued so great a development of linen manufacture, and of the demand for it from foreign markets, that a quickening of the process of bleaching be-

came necessary. A white color was also demanded, and so the use of more chemicals, with shorter exposures on the grass, became the rule. The manner of bleaching that has been carried on for many years past is something like the following: 140 webs of yard-wide brown linen, each one marked on the end with red thread in a way to be identified, are stitched together end to end into one piece of say 10,000 yards. This is called a "pot," and in common parlance is spoken of as "she." It is first passed through a solution of lime into the boiling pot, and there boiled eight or ten hours. It is then drawn through a tank of water. The webs are unsewn, each one is bundled separately, they are washed in the wash mills with pure water for an hour, then steeped in a sour of dilute hydrochloric acid, to convert the residue of the lime into a soluble salt; washed again in the mills, boiled in soda lye, which, combining with the waxes and fats in the fiber, make them into soap, and hence removable; washed again, put on the grass for some days, boiled again in lye, washed, put on the grass, rubbed in soap and water, boiled in lye, washed, put on the grass, and so on.

As soon as it is considered to be sufficiently boiled the whitening process is begun by the use of bleaching powder or "Dip" in which the cloth is left over night. It is washed, treated with weak sulphuric acid, boiled again with soda lye, such processes being repeated until the cloth is found to be of a proper whiteness. The webs are once more stitched together and the process of finishing begins: The cloth is breadthed, passed through a water mangle between rollers which leave just the proper moistures for taking starch, then into and through a tank filled with a mixture of blue and starch, after which it is passed over heated rollers to dry it. The webs are once more unsewn, they are put on the beetling beams and beetled for four or five hours, turned on the beams, and beetled for another four or five hours, and so on till they have had thirty to sixty hours of beetling. They are then aired, stretched to the full width, and calendered.

This completes the work of the bleacher, the whole occupying eight or twelve weeks. If an inquiry is made of a bleacher how is a certain pot coming on, or at what stage is it? the reply will probably be, "She" is doing well, or "She" is ready for the blueing. A witty, or shall I call him a wicked bachelor, once suggested that a pot was called "she" because of its being so hard to bring it to the right point! Linen bleaching is not only a very risky business, but it has also been an unprofitable one, so the Irish bleachers and the Scotch bleachers have recently been obliged to form an association binding them to regulate their prices and terms by common agreement. They are entitled to have a fair living out of their business, and may have it without injuring the other sections of the trade.

In linen bleaching there is a field for the services of chemical research. The present methods carry with them serious risks of damage to the goods. A pot may be taken as worth \$2,500, and in the North of Ireland seven or eight thousand of such pots are treated each year. One may thus form an idea of the magnitude of the risk. Here, then, is a practical object for our scientific men to have before them.

The preparation of linen goods for the market is a somewhat elaborate process. When the webs are received from the bleaching works they are carefully examined and any defective portions laid aside. They are then lapped or folded, and, it may be, ornamented to suit the taste in each market. Elaborate folding and costly ornamentation, once so common, are now, however, fast disappearing. Great changes have taken place in the methods of selling the products of flax, the tendency being to eliminate the middleman. Formerly spinning was the sole business of a firm, whose yarns, through one or more intermediaries, reached the weaver; weaving, the sole business of another firm, whose goods were sold to the merchants through another intermediary. Bleaching was the business of a third; the goods were then sold to a merchant-shipper, who sold to wholesale houses either at home or abroad, and these sold to the shops. But now two or more of these operations are the business of one firm, while some of the largest houses carry through all the operations, and by means of travelers, speaking the language of the countries where they go, sell direct to the wholesale houses abroad, and even in some

instances to the shops. Some firms also have, in the principal using centers, branch houses where stock is held, and is sold to the shops as they may require it in the currency of the country.

The Companies' Act of 1862 and later ones have been availed of largely by the firms engaged in the linen industry. The York Street Flax Spinning Company was the first in Belfast to be registered as limited. That was done in 1864. Almost every firm of any importance in the linen industry of Ireland is now limited. Some of them print their accounts and send them freely to their shareholders, and their shares may be bought by the public. Other firms are "private limited," do not publish their accounts, or allow their shares to be offered to the public.

It is an advantage, as tending to stability of its business, for a firm to be limited, in that money put into shares cannot be withdrawn from the company, whereas if a partner of a private firm dies his capital may have to be paid out, and that may cripple the firm. Limited liability also tends to facilitate the extension of a company's plant and operation as it is supposed to have a perpetual life, and the shareholders cannot be involved beyond the sum to which they are committed by the shares they hold, and further, the general public have, by means of it, access to participation in the profits of the industry.

In the linen industry there has been no amalgamation of firms, except perhaps the Linen Thread Company. But there have been working agreements among masters for the settlement of wages, for reducing output, and in one instance, to maintain a minimum price for yarns. This latter agreement among flax spinners, come to in 1908, to hold yarns in stock rather than sell them below the price that had been fixed, was irksome to some of the spinners, but it is now acknowledged by all of them to have been good for themselves and for all connected with the trade.

I must not omit to mention the large and prosperous linen thread industry, in which the leading firm is Messrs. William Barbour & Sons, Lisburn. If I do not enter on that interesting subject it is simply because I know too little about it. There are also many other branches of the linen industry which time will not allow me to speak of. A feature of the industry is the numerous ramifications into which it branches, and the comparatively small quantity of each article that has to be manufactured. This is indeed one of the safeguards of the position. It tends to prevent other countries, such as the United States, from making such goods themselves.

The relations between masters and employees in the linen industry are of a more friendly character than in most other industries. In many instances one generation is succeeded by its descendants, and sometimes to the third or fourth generation, in the service of the same company. Conferences in an amicable spirit have sometimes taken place and arrangements of wages been agreed upon without recourse to strikes, which have been rare and always of small dimensions.

A rough estimate of the capital employed in the Irish linen trade might be made up as follows: 935,000 spindles at an average price of \$25 each, \$23,375,000; 36,000 power looms at \$250, \$9,000,000; bleaching, printing, and finishing works, estimated at \$2,500,000. These amounts added together would show a total of \$34,875,000 in plant alone; in addition to which the stocks of raw material and of goods in process of manufacture and in a finished state would be value for \$25,000,000 or \$30,000,000. Then there is a further amount of capital employed in giving credit to buyers, and, whether this be in the form of discountable bills or of open accounts, capital to the extent of over \$10,000,000 is required to do it. The grand total of capital employed would thus amount to at least \$70,000,000.

One might estimate the amount paid in wages to the operatives as follows: 70,382 men, women, and young persons, at an average of \$3.12 per week, \$11,435,000; bleachers, printers, and finishers, \$2,020,000; embroiderers, hemstitchers, and warehouse hands, including lappers, ornamenters, and box-makers, \$2,000,000; hand-loom weavers, \$275,000. Besides all these there are clerks, managers, and other officials whose salaries would amount to \$1,250,000; and if 5 per cent on capital, \$3,500,000, be included it would show a grand total of \$20,360,000 distributed annually; and three-quarters or more of it is drawn from foreign countries, as much

* Journal of the Royal Society of Arts.

the greater portion of Irish linen products is sold outside of the United Kingdom.

Linen manufacturers ought, of course, to manufacture nothing but linen goods. Unfortunately the stress of circumstances forces them to extend their manufactures to unions, that is, goods into which enter both linen and cotton yarn. In order to meet and satisfy, as far as possible, a craving on the part of buyers for low-priced goods, having some appearance of linen, this has long been found necessary. The making of unions is justified in the case of fancy dress goods, as undoubtedly cotton takes and holds dye stuffs better than linen, the fiber of it being softer and more penetrable. Very beautiful and becoming dress goods are being woven in such unions. But into that part of the trade I shall not enter. What has been set as my text is *linen*—linen the most ancient of textile fabrics. It is hoary with age, and with the most sacred associations and charming memories, and that it should have to struggle for life now in the fiftieth or perhaps the one hundredth century of its useful existence is at least pathetic. Cotton is known to have been in use as a textile for 2,000 years or so. The name calico was given because it was first

shipped to us from Calicut in India. It was in America before Columbus. But, as compared with linen, the cotton industry, its great and formidable rival, is a juvenile. It is only within the last 100 or 150 years, by the invention of the spinning jenny, the power loom, and the fly shuttle, that cotton has come really into common use, and that its industry has assumed the gigantic proportions of to-day. The linen merchant now meets it as an opponent at every turn, and he is so hedged in by it that the linen industry has been barely able to avoid a serious contraction.

Among the reasons why cotton is so formidable a competitor of linen, the following may be mentioned. Although the cost of flax and of raw cotton do not differ very much, cotton has a great advantage over flax in the ease and cheapness with which it is manufactured. In the first place, the hard and inelastic nature of the flax fiber makes a much more expensive type of machinery necessary for its spinning. A cotton mill can be erected complete for about \$6.62 a spindle, whereas a flax-spinning mill would cost from \$30 to \$40 a spindle. Then the great variations produced in any one field of flax necessitate elaborate and costly hackling and sorting, in which

about 50 per cent of it becomes tow of comparatively low value, raising the cost of dressed flax fully 50 per cent above that of raw flax. Cotton, on the other hand, is very uniform in quality, and is cheaply carded with little loss of material or of weight. Its elasticity allows of the employment of machinery so largely automatic that the number of workers in a cotton mill would be about one quarter of those in a flax mill of the same number of spindles, while at the same time the turn-off of a cotton spindle is considerably greater than that of a flax spindle. The advantage in favor of cotton does not end with its conversion into yarn, for it is more easily woven than linen, and finally it is bleached more quickly, with less risk of damage, and with less loss of weight. Nothing but the inherent beauty and excellence of the flax fiber has permitted its survival of competition so formidable. The position of the linen trade is a trying one, but the experience of the past leads to the hope that the staple trade of Ulster will continue to survive during many future generations. To have held the supremacy in the fine linen trade against the world is, I trow, another flag saved by Ulstermen for the British Empire.

SHELLAC AND THE LAC INDUSTRY.*

A MYSTERIOUS AID TO CIVILIZATION.

BY G. CLARKE NUTTALL, B.SC.

SHELLAC or lac is one of those aids to civilization about which there has tended to be an atmosphere of mystery and romance.

Already familiar to us in the form of sealing wax, varnish, furniture polish, hat-stiffening, and the like, and, of course, in the decoration of every conceivable thing hailing from India—trays, boxes, tables, beds, shields, and a hundred and one other things—it is, nevertheless, quickly rising now into vastly greater importance because it has been found essential in electrical work (whose immense development has been of such mushroom growth the past few years), and because, too, it is largely required in the preparation of gramophone records. Hence the exports from India have quadrupled, and in 1905 no less than 6,000 tons of it were imported into the United States alone.

Now the lac industry is of great antiquity. Thousands of years ago, in prehistoric times, the natives knew its value and used it largely. There are various references in Sanskrit literature to the lac tree, that is, to the palas or dhak. In 1590 the great Akbar wrote full particulars as to how lac resin should be used in varnishing the wood of public buildings. The first European who described it was a Dutchman who was sent on a scientific mission to India in the sixteenth century by the King of Portugal. He published his knowledge of its use and value in 1596—a translation was soon after made in England—but he had no idea whatever of the true origin of the wonderful resin. Since that time, it is true, we have learnt much about it, but with this sudden leap in value and importance there has now come a great accession to our knowledge.

Last year, in an admirable treatise, the Forestry Department of the government of India, through Mr. Stebbing, enabled us, perhaps for the first time, to obtain a perfectly definite and clear idea of its origin, nature, and manipulation, and of the life history of the insect to which it owes its existence. For shellac, or lac, as it is generally termed in the initial stages, is a product of the animal kingdom, and may be defined as a resinous excretion by a scale-insect known as *Tachardia lacca*, a close relative of bugs, plant lice, and the like, and a native of India. It lives upon many varying native trees, though the kusam (*Schleichera trijuga*), the dhak (*Butea frondosa*), the pipal (*Ficus religiosa*), and the arhardal (*Cajanus indicus*) are its favorites. It is also found, at times, upon the banyan (*Ficus bengalensis*) and upon the mango (*Mangifera indica*).

Great numbers of these insects dwell closely together upon the trees, and each proves to be nothing more or less than an animated miniature syphon. At the mouth of every one is a tiny lancet with which it pierces the tree, and through the opening thus made it inserts a sucking apparatus. Then it proceeds to draw up into itself the living sap of the tree; this passes through its body, is modified in the process, and passes out again at the other end in the form of lac. The lac accumulates and is gradually built up round the insect into a small, red dome-shaped excrescence. Owing to the myriads of these excrescences they tend to run into one another and form a regular incrustation on the branches.

The life history of the insect may be summarized as follows, though it varies in detail in different parts of India: About the beginning of July tiny red larvæ can be seen swarming out of the incrustations in countless numbers and spreading over the neighboring twigs. Each is oblong in shape, with two minute eyes, two short antennæ or feelers, and six short legs. Curious tufts of white powdery hairs—the breathing apparatus—grow from each side of the thorax. This swarming goes on for two or three weeks, not all the insects appearing at the same time, but each, as it appears, immediately sets to work to find a suitable

SIDE AND DORSAL VIEWS OF THE LAC INSECT.

position where it can set up as a "syphon" on its own account. Within twelve hours its fate is sealed, and during this time it takes no nourishment of any kind, as its whole attention is taken up with settling itself in life. A certain number will be successful, but a far larger number are doomed, owing to their not being able to bore through the cortex at the point they attempt it, and hence cannot get at the sap.

A successful insect, however, settles to work, and for about two and a half months goes on steadily forming lac incrustation, the female producing a bigger structure than the male. At the end of this time the males creep out backward from under the edge of their scales; they have grown a little since we saw them first as larvæ, and have now larger antennæ and four eyes instead of two (two more having appeared under the head), and they crawl over the twigs looking for the females, and fertilizing them. Then they die, their life work quite finished. The females go on forming lac for another two and a half months, and developing too; then for a month, the last month of their lives, they rest dormant, taking no nourishment, lying inert. The eggs hatch out within them, perhaps a thousand in number in each, and the larvæ emerge and swarm, trying to find new homes while the mothers shrivel and die.

There are thus two generations in every year, the second generation beginning to swarm in the early part of December and distinguished by the single fact that the males have wings.

Now, the lac insects have various enemies to contend with during their short life. Birds are on the

outlook for the larvæ when they first swarm, and monkeys like the sweet-tasting lac, and will eat it in considerable quantities and include the insects, too, in their meal. Ants are still greater pests to them, for though they do not deliberately eat up the insects themselves, yet they feed on the lac with avidity, and often injure the insects in so doing. Certain caterpillars, too, will prey upon the lac insect, and rain, frost, and hail are often injurious to large numbers.

Lac is almost invariably collected by natives, and the collection is made by breaking off the incrustated branches and twigs. These are sold as "sticklac" to middlemen who take them in large quantities to factories. Here they are broken up into short lengths and crushed either by hand or by machinery. This crushed matter is divided into three parts—(1) the wood, which is used up as fuel; (2) the dust—"khud"—sold to makers of bangles and toys; (3) the true granular lac which is known as seed lac. The next process is to wash the seed lac for twenty-four hours; the water which runs away from it is a deep purple color and formed the once valued lac-dye, but is valuable no longer, as it has been supplanted by aniline dyes. Drying follows, the substance being spread out and finally bleached. At this stage it is often mixed either with resin to lower its melting point, or with orpiment (yellow arsenic) to make it opaque, or with both substances at once. The mixture is then put into very long, narrow cloth bags, 10 to 12 feet long and 2 inches wide, and held over open fires. The worm-like bags are slowly twisted and the melting lac oozes and drops on to the floor. It is then stretched into thin sheets and sold as shellac. All fragments and parings are carefully secured throughout the whole manufacture; nothing is wasted, and these inferior qualities are sold as button-lac and garnet-lac.

Hitherto the cultivation and collection have been almost entirely in the hands of the natives, and hence the methods employed are of the original primitive character. But now shellac is becoming so valuable and the demand for it is increasing so fast that the government of India is beginning to interest itself more closely in lac cultivation, and the Forest Department has been intrusted with the work of forming lac preserves. The matter has become more urgent during the past four years since the price began to rise, and prompt action is felt to be advisable. In 1896 the value of the export from Bengal was 1,38,55,770 R. In 1906 it was 3,14,82,409 R., and yet the actual difference in quantity exported was only between 204,072 cwts. in 1896 and 271,101 cwts. in 1906. The total export from India in 1906 was of the value 3,31,39,706 R.

It must be realized that all these facts concerning the life history of the insect are of the greatest importance. If the government is to extend successfully the lac industry it must ascertain them before it can know the best time and methods of propagating the insect and the proper trees on which it can thrive. Many absolute failures in promoting lac cultivation in the past were entirely due to ignorance of these facts, as, for instance, mistaking the swarming of the male insects for the swarming of the larvæ. During the past two years considerable research and elucidation of the problems of lac cultivation has been done

* Knowledge and Scientific News.

HEREDITY.

Concluded from Front Page.

Heredity has for the stockman and plant-breeder a well-recognized commercial value, because by a knowledge of its laws he is enabled to produce in greater number or with greater certainty animals or plants of a particular type. Indeed, much of our present knowledge of heredity has been derived from a study of the domesticated animals or of the cultivated plants, and from the same sources we may expect to continue to draw, for here alone have we an unobstructed field for observation and experiment, the indispensable tools of scientific research. Just as the sciences of anatomy, embryology, physiology and pathology progressed but slowly so long as the phenomena of the human body alone were considered, but advanced by leaps and bounds when comparative studies on other animals were undertaken, so concerning heredity in man we have learned and can expect to learn but little from the study of man alone, but much from a study of other animals and of plants and from a comparison of the phenomena in the two cases.

the body as a result of use, disuse or other agencies are not inherited, because they have not affected the constitution of the germ-plasm carried within the body.

Weismann's two principles are of fundamental importance to a right understanding of heredity. They are: (1) That the germ-plasm is independent of the body containing it, or, as Weismann put it, that the germ-plasm is continuous from generation to generation, whereas the body dies, and (2) that acquired characters are not inherited.

The hottest biological discussions of the last twenty years have been waged over these two principles and the contest is by no means ended, but year by year the correctness of Weismann's contentions is more generally admitted.

Common experiences support both principles. Thus the independence or continuity of the germ-plasm has been shown from time pre-historic in the practice of castration upon the domesticated animals or upon man. The germ-plasm is localized in particular organs

vidual, whether an animal or a plant, has its beginning in the union of two bits of germ-plasm, an egg cell furnished by the mother and a sperm cell furnished by the father. Whether the union of the germ-plasm takes place within the maternal body or not is quite immaterial; among a great many animals it does not.

The new individual, it will be observed, is dual in origin, and to its dying day it retains a dual nature. For the maternal and paternal contributions of germ-plasm retain a certain distinctness as we shall see, and may in part separate from each other at reproduction.

Each germ-cell (egg or sperm), so far as its contribution to heredity is concerned, stands for a complete organism of its species, bears the potentialities of a complete organism, and under appropriate conditions can develop into such an organism. For this idea we have strong experimental evidence. It has long been known that the eggs of certain species of animals can develop without fertilization, i. e., without

FIG. 9.—A DARK SMOOTH GUINEA-PIG.

FIG. 10.—A WHITE ROUGH GUINEA-PIG.

FIG. 11.—A DARK-ROUGH GUINEA-PIG.

The new combination of characters obtained when animals are mated like those shown in Figs. 9 and 10 respectively.

FIG. 12.—A WHITE SMOOTH GUINEA-PIG.

A second new combination of characters, but obtained first among the grandchildren of such animals as are shown in Figs. 9 and 10. Other grandchildren are like the respective grandparents (Figs. 9 and 10) or the parents (Fig. 11).

HEREDITY.

Every new individual arises out of material derived exclusively from its parents. This is the basis of heredity. But it does not follow that the new individual will resemble its parents merely. It may resemble remote ancestors more strongly than either parent. For it represents a combination of materials or of qualities derived from the two parents, and it is possible that neither parent may manifest all the peculiarities which it transmits to the offspring. For the parent is made up of two distinct parts, its own body and the reproductive substance contained within that body, and the two may not be identical in character.

The reproductive substance has been called by Weismann the germ-plasm. He it was who first clearly recognized the fact that the germ-plasm is distinct from the body which contains it, and that the influences which modify the character of the one do not of necessity modify the character of the other. Thus he was able to show experimentally that mutilations of the body, as loss of the tail in mice, are not inherited, and to establish with a considerable degree of certainty the principle that characters acquired by

of the body, the reproductive glands. If these are removed reproduction becomes impossible, though all other functions of the individual persist. Further, it is possible to show experimentally that the germ-plasm transplanted from one individual into another retains the character which it originally had, quite unaffected by the changed body with which it is associated. This Dr. John C. Phillips and the writer have recently shown in the following way. The ovaries were removed from a young black guinea-pig, Fig. 1, and these were transplanted into the body of a white guinea-pig, previously castrated, Fig. 2. The white guinea-pig was now mated with another white guinea-pig, Fig. 3. Normal white guinea-pigs produce only white offspring when mated with each other, but these two have now produced in three successive litters six young, all black. Three of these are shown in Fig. 4. Evidently the germ-plasm of the black guinea-pig retained its original character even after transplantation into the body of a white one.

In order better to understand the processes of heredity we should be familiar with what takes place when a new individual is formed. The new indi-

vidual having united with a sperm or male sex-cell. In such cases there can be no question that the potentialities of an entire organism are contained in the egg, for without any outside help the egg develops into a complete individual of the species. In recent years it has been shown that the eggs of many species in which fertilization normally occurs may by artificial means be made to develop without having united with a sperm. This is true of the eggs of sea-urchins, starfishes, and of certain worms and mollusks. Such eggs artificially stimulated to development produce entire individuals, similar to those produced by fertilization, but possibly less vigorous.

On the other hand, a sperm cell may be made to develop, if it is allowed to penetrate into a fragment of an egg, even a fragment which lacks the important cell-nucleus. In such cases the entire nuclear material of the embryo is furnished by the sperm, yet the embryo so produced is complete, lacking no essential part, and similar except in size and vigor to normal embryos produced by fertilization.

Accordingly the evidence is fairly complete that each germ-cell (egg or sperm), considered as the

vehicle of heredity, represents a complete organism, and that an individual produced by the union of two such germ-cells represents twice over each heritable trait of the species. In other words, the germ-cell is single, the individual is double.

This fundamental principle of the singleness of the germ in contrast to the doubleness (duality) of the individual receives the fullest confirmation from experimental breeding.

If we mate a pure-bred black guinea-pig with a white one, the young are all black pigmented. This result seems to violate the principle previously stated that both parents contribute equally in heredity; in reality, however, that principle is not violated. The white parent has contributed its own character to the offspring, but that contribution is unseen in them simply because black hides it. The white will reappear among the grandchildren. In Fig. 5 we see a mother guinea-pig having a jet black coat. Beside her are four young of the same color as herself. The father too was black. In a word this black race breeds true. A female of this race was mated with the albino male shown in Fig. 6. Albinos have white hair and pink (unpigmented) eyes, the red eye color being due to the blood which shows through; they breed true among themselves, but the result is very different when they are mated with black individuals. Two children of the albino male and the black female are shown in Fig. 7. They are intensely black pigmented, as are all the young produced by this cross. Two of them when grown to maturity and mated with each other produced a litter of four young, shown in Fig. 8. Three are black pigmented like the parents, but one is an albino similar in all respects to the albino grandsire. Here we notice the reappearance of the albino character after skipping a generation. The albino grandsire really made a hereditary contribution as regards the character hair color, but it did not show in the children, because black also was present in the children, and black obscured or dominated the white.

Applying our principle of single germ, dual individual to this case, we see that the facts observed are fully in harmony with it. The original cross brought together the character B (black) and W (white) into an individual (or zygote as we call it, a joining together) BW, which showed only black. Two such individuals, a male and a female, were now mated together. In the formation of germ-cells by these individuals there is a return to the single condition, B separates from W and passes into a different germ-cell. Accordingly, the mother forms eggs, B and W, respectively, and the father forms sperms of a like character. Now a new individual arises from a union of an egg with a sperm. Apparently either sort of sperm may unite with either sort of egg which it chances to meet. So there are formed in the next generation three sorts of zygotes (individuals), viz., BB, BW, and WW, instead of BW alone as in the previous generation. The chances for the occurrence of these three sorts of unions are 1 BB, 2 BW, and 1 WW. Any individual containing the character B will be black; accordingly the BWs as well as the BBs will be black and there should be three blacks to one white. These are in fact the observed proportions. The white individual should transmit no other character because it contains only W. Such is indeed the observed fact. Any two white individuals mated together will produce only white offspring. But, if our reasoning is correct, two thirds of the black individuals of this generation (viz., the BWs) should transmit white as well as black, while the remaining one third, BB, should transmit only black. Experiment justifies both these conclusions. If we mate the black animals of this generation, one by one, with albinos, we find that on the average two out of three of them will produce white offspring as well as black ones, while the third one produces only black offspring.

The scientific law which governs the inheritance of albinism, and of other characters transmitted in a similar fashion, is known as Mendel's law. It applies, apparently, to all cases of color-inheritance, as well as to the inheritance of characters of many other sorts. Through its operation new combinations of the peculiar characters of individuals or of races can be obtained in the course of one or two generations. Thus when a guinea-pig showing the two coat-characters seen in Fig. 9, dark and smooth coat, is mated with one showing the combination, white and rough, Fig. 10, young are produced showing a wholly new combination, dark and rough, Fig. 11. And if these young are at maturity bred together, a fourth combination, white and smooth, appears among their young, the grandchildren. See Fig. 12. Other grandchildren manifest the combinations seen, respectively, in the parents and in the grandparents. By selection any one of these combinations may be obtained in a pure race.

Oftentimes a new combination of characters obtained through crosses coincides with a lost racial combination. Then the phenomenon is called reversion or atavism. Thus when yellow rabbits are crossed with black ones, gray offspring are obtained similar to wild rabbits in coloration. There is no longer any-

thing mysterious about the process; it is simple recombination of different unit-characters formerly associated together in the same race, but since isolated in some of the derived races.

Very different in nature, apparently, from the Mendelian inheritance of unit-characters is the result obtained when races of animals are crossed differing in size or in the proportions of their parts. In such cases the children are intermediate in character, and the grandparental conditions do not reappear among the grandchildren. The result may be described as a blend apparently permanent. Fig. 13 shows the skulls of three rabbits, all adult, father, mother and son. The skull of the son is shown between that of his parents, the mother's skull being at the right. Size and proportions of parts are clearly intermediate in the son. No grandchildren were obtained like either grandparent in size. The color of the coat in this same family of rabbits clearly followed Mendel's law, although the size characters blended. The practical result is that one may at will produce a race of rabbits of any desired size within the known limits of variation in size among rabbits, and with any of the conceivable combinations of color factors. Size variation

of rows of Lahaina can cuttings (each cutting having two eyes) were planted out. Six of the rows were planted with cuttings inoculated with the pineapple disease; of these six rows, three had had the cuttings soaked in Pickering's mixture for one hour, one in water, and one in normal Bordeaux mixture also for one hour, while the remaining row had untreated cuttings. The other six rows only differed in that their cuttings were not inoculated. It was found that Pickering's mixture injured the cuttings seriously, more than half of the eyes failing to germinate. The inoculated cuttings were much poorer than the non-inoculated ones, thus showing that the pineapple disease was able to enter the cuttings despite the presence of an excess of copper sulphate. The investigation proved conclusively that Pickering's formula should not be used in preparing Bordeaux mixture for the treatment of can cuttings; it also showed that copper sulphate can materially injure or even kill the eyes of can cuttings, so that in preparing Bordeaux mixture for the treatment of cuttings, care should be taken that no considerable excess of copper sulphate is present in the mixture; this can be avoided by the use of a proper amount of lime. The cuttings treated

FIG. 13.—SKULLS OF THREE RABBITS.

Mother (3 and 3a); father (1 and 1a); and son (2 and 2a). From publication No. 114 Carnegie Institution of Washington, by permission.

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is apparently continuous and its inheritance blending, color variation is discontinuous and its inheritance Mendelian.

Notwithstanding the seemingly radical difference between these two types of inheritance, it is possible that they may, after all, prove to have a common basis. Blending inheritance may possibly be only a complex sort of Mendelian inheritance, in which many independent factors are simultaneously concerned. The question is one of much theoretical interest. Its solution awaits further investigation.

What has already been accomplished in the study of heredity gives us a hopeful outlook for the future. We are gaining a fuller knowledge of its processes, and a knowledge of processes is a first step toward their control.

W. H. Lyon in the Hawaiian Planters' Monthly writes on Pickering's Bordeaux mixture. According to Pickering, the chief aim in making Bordeaux mixture should be to reduce the lime to the lowest possible proportions consistent with the precipitation of all the copper. Comparative experiments have been made with a view to determining the effect of treating sugar cane cuttings with Pickering's mixture. Twelve paral-

with normal Bordeaux mixture were found to give the best and most rapid germination.

The Swiss Commission appointed to investigate the question of earth as the return circuit in direct-current systems has recently issued its preliminary report. After some introductory tests, the permission of the Lausanne Corporation to run with the earth as the return circuit on the Saint Maurice-Lausanne line was readily obtained, but the railway telegraph authorities noticed disturbances in certain of their lines and so refused permission at first. The difficulty was, however, got over in 1908 by the simple device of inserting a few opposing cells in the telegraph lines affected and so neutralizing the action of the drop in the (constant current) earth return. The arrangement proved so effective that the desired permission was then obtained, and after the necessary batteries had been put into use at four of the stations along the line the earth return service was adopted, and has been in regular use from August, 1908, up to the present time without any interruption. The return circuit can be changed over from "earth" to "line" (a second wire being available) at any time if desired in three or four minutes.