and the air was motionless. The shade temperature reached 40·5 C. in the course of the day. Time was taken as portions of 5 cubic centimetres were distilled. The shortest time in which this quantity passed was 3m. 20s. This is at the rate of 1·5 c.c. per minute, and it occurred twice in the forenoon, namely, at 10h. 37m. and at 11h. 23m. As the collecting area of the reflector was 904 square centimetres, this corresponds to 16·6 c.c. distilled per minute per square metre. If we apply a correction for 20° zenith distance it becomes 17·04 c.c. The evaporation of 17·04 grammes of water at 100° C. requires 9116 gr.° C. of heat, so that the heat actually collected and used in making steam was at the rate of 9116 gr.° C. per square metre or 0·9116 gr.° C. per square centimetre per minute. Converting 9116 gr.° C. into work at the rate of 0·425 kilogramme-metres per gramme-degree, we obtain as the realised working value 3875 kilogramme-metres per minute or 0·87 horse-power per square metre. The reflector consists of one mirror inclined at an angle of 45° to the axis of the instrument. This mirror throws all the reflected rays normally on the surface of the axial boiler. The larger mirror outside and the smaller mirror inside of this one throw their reflected rays inclined at small angles to the normal. Taking all the reflected rays together their mean normal component is 94 per cent. of the total reflected rays. It is therefore legitimate to increase the above figures in the proportion of 94 : 100, giving 0·93 horse-power or 9700 gr.° C. per square metre per minute. The mirrors are not perfectly reflecting, nor is the blackened surface of the boiler perfectly absorbing. An allowance of 7 per cent. for these deficiencies will not be thought extravagant, and we have in round numbers the work-value of the sun's vertical rays on the surface of the earth at or near the sea-level as 1 horse-power per square metre; the equivalent of this in heat is 10,300 gr.° C. per square metre per minute, or 1·03 gr.° C. taking the square centimetre as unit of area.

Mr. Michie Smith informs the writer that the highest rate which he has observed is 1·754 c.c. distilled per minute at a height of 7000 feet above the sea. This is exactly seven-sixths of the maximum rate observed on the banks of the Nile. If we imagine that in the most favourable circumstances the radiation as determined in Egypt might be improved in this proportion we get 1·17 horse-power per square metre and 1·202 gr.° C. per square centimetre per minute as a value of the heating power of the sun at the sea-level, which is probably very near the truth.

Comparing these results with those already quoted, we see that they agree with Crova's summer values as determined at Montpelier and lie midway between Vallot's (1891) values for Mont Blanc and Chamonix. We arrive therefore at the conclusion that the rate at which the surface of the earth at the level of the sea receives heat in the most favourable circumstances from the vertical sun is 1·2 gr.° C. per square centimetre per minute, or 1·17 horse-power per square metre. In discussing questions of terrestrial physics it would not be prudent to postulate a more abundant supply.

If we ascribe to the atmosphere a coefficient of transmission no greater than two-thirds, the value of the *solar constant*, or the heating power which the sun's rays would exert on a surface of one square centimetre exposed to them for one minute at a point on the earth's orbit, is 1·8 gr.° C. As the transmission coefficient is probably greater than two-thirds, the value of the solar constant is probably less than 1·8. Vallot, by giving effect to the rate of absorption actually observed in the air separating his two stations, arrives at 1·7 gr.° C. as the most probable value. These values are in substantial agreement with the older ones, such as those of Herschel and Pouillet; but there is a feeling at present that not much weight is to be attached to these results, and much higher figures seem to be more readily accepted. In a recent work, "Strahlung und Temperatur der Sonne," p. 38, J. Scheiner sums up the discussion of this subject by giving 4 as the most probable value of the solar constant.

As we have seen, the heat which arrives at the sea-level has to support the temperature of the land and that of the sea; it has also to supply the energy for all the movements of the ocean; it has to warm and expand the air, and to furnish the latent heat represented by the aqueous vapour in the atmosphere, and it is mainly accountable for winds and storms. All this is maintained on less than 1·5 gr.° C. per square centimetre per minute. But when the above catalogue of functions has been repeated, there is nothing left to be accounted for. If the sun's rays enter at the top of the atmosphere with an intensity of 4 and come out at the bottom of it with an intensity of only 1·5, how is the loss to be accounted for? It represents nearly double the energy which reaches the sea-level and produces such far-reaching effects. If it really entered the atmosphere it must be still there, either as heat or as its equivalent. But we know that the air is not made appreciably warmer by it, and we see no mechanical manifestations which can in any way be put forward as an equivalent. We conclude therefore that there is no excess of heat of this order to be accounted for, consequently values of the solar constant of the order of 4 are exaggerated.

J. Y. BUCHANAN.

REFLEX ACTION AND INSTINCT.[1]

IN the Paris *Journal of Anatomy and Physiology* of 1869 there was reported by Robin an experiment on the body of a criminal whose head had been removed an hour previously, at the level of the fourth cervical vertebra. The skin around the nipple was scratched with the point of a scalpel. Immediately there ensued a series of rapid movements in the upper extremity which had been extended on the table. The hand was brought across the chest to the pit of the stomach, simultaneously with the semiflexion of the fore-arm and inward rotation of the arm, a movement of defence as it were.

Probably none of us have seen quite so impressive an illustration of reflex action as the above, but most of us have watched the experiment in which a frog, having been decapitated and a drop of acid having been applied to its skin, the foot of the same side is brought up to wipe away the acid, and if this foot be cut off, after some ineffectual efforts and a short period of hesitation, the same action will be performed by the foot on the opposite side. These symptoms of apparently purposive action on the part of a brainless body have always struck me as most strange.

Some four years ago I had the privilege of reading to you a paper on memory, from which I will now quote:—"When we attempt to acquire some new feat of manual dexterity, involving a series of combined muscular movements, such as a conjuring trick, we find that, when first attempted, each movement has to be thought out, and the whole is effected with difficulty. Every time that the process is repeated the action becomes more easy; each movement of the muscles involved follows its predecessor with greater readiness, and at last the trick becomes apparently one action, is performed without thought, and may be said to be automatic. The nerve structures involved have acquired a perfect memory of what is required of them; each takes up its part at the proper moment, and hands on in succession an intimation to its neighbour that it is time to transmit the expected impulse. Nerve centres have been educated. An organic memory has been established."

I went on to give instances in which, by frequent practice, actions had become so habitual as to take place on the application of the stimulus without the will of the individual, and even contrary to his wish. I gave as an illustration the story of the old soldier who was carrying a pie down the street, when some one mischievously crying "Attention!" down went the soldier's hands to his trousers seams, and down went his dinner in the mud.

Let us apply this effect of constant practice to the case in question. The frog has a smooth, soft skin, unprotected by hair or scales. His haunts are stagnant water which swarms with injurious insects and other enemies; or the banks of ponds and streams abounding in sticks and stubs. From the time when the first progressive tadpole protruded his incipient legs, the race of frogs has been brushing away irritating substances. The nerve cells of their spinal cords have established such relations that, whenever a sense of irritation is conveyed to sensory cells, motor cells in connection are brought into action, and a complicated muscular movement follows, without the necessity of the interference of the will.

We may compare the association of nerve cells in the spinal cord to a group of men highly drilled in particular evolutions. Each individual cell of the group maintains relations with others near it by some one or more of its many arms. Upon the receipt of the intimation through sensory nerves and cells that there is, something burning a particular portion o the frog's skin, motor

[1] A paper read before the Derby Medical Soc ety b W. Benthall, M.B., on April 9, 1901

cells accustomed to act with these sensory cells send out messages to particular muscles. If the message is responded to, if the foot comes up and the offending particle is brushed away, the stimulus and the effort cease. If the stimulus still goes on, other cells which supply accessory muscles are called into play. If this effort to remove the offending matter is vain, and the irritation still goes on, the stimulus is passed on to other cells, which have in an emergency previously been in the habit of assisting; the stimulus thus travels to the opposite side of the spinal cord, and the other leg now comes up to the point required.

It is the effect of drill, of practice, in the forgotten past. I am aware that in making this statement I am assuming the inheritance of acquired powers—an assumption directly in opposition to the views of Weismann, who maintains that no powers acquired during the lifetime of the individual are transmitted to the progeny.

The development of the reflexes and instincts which we shall refer to will be seen to be of such importance to the maintenance of the life of the individual or to the procreation of its race; that the slow and gradual formation of nervous connections can probably be explained by the Weismann theory; but for our purposes to-night the assumption of the inheritance of acquired powers enormously increases the ease with which we can understand their development.

The idea of this paper is therefore that, as in the *individual*, constant habit causes in time such a free connection between nerve cells as to facilitate the passage from cell to cell of a particular stimulus until the action follows the stimulus automatically, so in the *race* a particular response to a particular stimulus has been repeated so often that the connection has become congenitally perfect, has become in fact what we know as a reflex. And, further, that the frequent repetition of particular actions under similar stimuli have so influenced the *intelligent* actions of the animal, that *they* also have become engrafted upon the nerve system, and recur under the influence of similar stimuli in an automatic manner; the result of these reactions of the intelligence to a particular stimulus being what we know as instincts.

The great advantage of a reflex is the certainty and usually the rapidity with which it acts. The response to the stimulus does not have to travel round through the brain. It takes a short cut. With imperfect reflexes the animal is at the mercy of its surroundings.

Nature does not pass imperfect work. The eye reflexes, for instance, have been developed by constant practice. If through their failure an animal were partially blinded, some self-constituted Factory Inspector in Nature's workshop would soon get on the blind side of that animal, and there would be no chance of its perpetuating its failings. If the cough reflex failed, some septic fly would quickly start a fatal pneumonia.

Assuming that all reflexes have been developed by practice, it follows that our own are not merely aids to the diagnosis of disease at the hands of the physician, but are now, or have been, of use in some period of our history.

A year or two ago, in the *British Medical Journal*, there was a very interesting description of the strength of the reflex grip of the newly-born infant, this being sufficient to maintain the weight of the child for some minutes while hanging from a stick. This the writer attributed to the necessities of a time before perambulators, when a child had to hang on for bare life to its mother's hair or clothes. The inward-turned feet of the newly-born child and the plantar reflex point to a time when the feet were used for climbing and for grasping.

Many of the superficial reflexes were probably developed to get rid of flies and other irritants which must constantly have troubled the naked body. The reflex action exhibited by the decapitated body, described at the commencement of this paper, was attributed by the observer to an attempt at self-defence. I think it was more probably an attempt at scratching, an act which was probably habitual in our hairy ancestors, as it is now in our poor relations at the Zoo—a movement, in fact, strictly analogous to the movement of the frog's foot incited by the irritation of the acid. To assume that there was an intention of defence in the action imports into the movement an element of consciousness for which in the absence of the brain we have no warrant; and this brings us to the question of instincts, which have been defined as reflex actions into which an element of consciousness has been imported.

I will endeavour to trace an ascending scale of instincts showing their dependence on reflex excitation. A newly-born infant has to be placed to the breast; it then seizes the nipple with its lips and sucks. There is little difference between the reflex action incited by the contact of the maternal nipple with the infant's mouth and the cough or sneeze reflex; both are complicated actions of many groups of muscles. In the one case, spasmodic; in the other, rhythmical. The young of the rabbit, born blind and helpless, nuzzles about till it finds a nipple, and then takes its hold. The lamb, calf, or fawn, guided by sight and smell, *seeks* its mother's teat. In each of these cases a stimulus is required, either of touch, sight, or smell. Without the stimulus the experiment fails.

Fawns are peculiarly precocious. From the first they show a tendency to couch and hide on the approach of danger. The following is an extraordinary instance of combination of maternal and infant instinct:—

"I have had frequent opportunities," says the "Naturalist in La Plata," "of observing the young from one to three days old of the *Cervus campestris*, the common deer of the Pampas, and the perfection of its instincts at that tender age seems very wonderful in a ruminant. When the doe with fawn is approached by a horseman, even when accompanied by dogs, she stands perfectly motionless, gazing fixedly at the enemy, the fawn motionless by her side; and suddenly, as if at a preconcerted signal, the fawn rushes away from her at its utmost speed, and going to a distance of 600 to 1000 yards, conceals itself in a hollow in the ground or among the long grass, lying down very close with neck stretched out horizontally, and will thus remain until sought by the dam. When very young it will allow itself to be taken, making no further effort to escape. After the fawn has run away, the doe still maintains her statuesque attitude, as if to await the onset; and when, and only when, the dogs are close upon her, she also rushes away, but invariably in a direction as nearly opposite to the fawn as possible. At first she runs slowly with a limping gait, and frequently pausing as if to entice her enemy on, like a partridge, duck, or plover when driven from its young; but as the dogs begin to press her more closely her speed increases, becoming greater the further she succeeds in leading them from the starting point."

In considering this case we have to remember that the deer is, as a rule, a woodland animal, and that its fawn, while feeble, crouches under cover, of which there is plenty within immediate reach; but the deer of the Pampas lives on rolling prairies where the only cover is the isolated tufts of Pampas grass. While, therefore, the instinct to crouch is sufficient for the fawns of most deer, crouching in the immediate neighbourhood of the surprise would be useless in the open ground of the Pampas; and this artful combination of tactics has doubtless been developed by practice.

In birds we get even more marked differences in connate powers and instincts, from the naked young of the sparrow, which is nearly as helpless as the human baby, to the newly-hatched chicken, which is a regular little man-about-town at once. The habits of the latter have been closely studied. Hatched out in an incubator, and deprived of all maternal instruction and example, he quickly begins to peck at all small objects, with a preference for moving ones, and from the first shows an almost perfect power of estimating distance and direction, which is very marvellous when we consider the great number of muscles which have to be co-ordinated in the act.

The late Mr. Douglas Spalding placed beyond question the view that all the supposed examples of instincts may be nothing more than cases of rapid learning, imitation, or instruction, but also proved that a young bird comes into the world with an amount and a nicety of ancestral knowledge that is highly astonishing. Thus speaking of chickens which he liberated from the egg and hooded before their eyes had been able to perform any act of vision, he says that on removing the hood, after a period varying from one to three days, "almost invariably they seemed a little stunned by the light, remained motionless for several minutes, and continued for some time less active than before they were unhooded. Their behaviour was, however, in every case conclusive against the theory that the perceptions of distance and direction by the eye are the result of experience or of associations formed in the history of each individual life. Often, at the end of two minutes, they followed with their eyes the movements of crawling insects, turning their heads with all the precision of an old fowl. In from two to fifteen minutes they pecked at some speck or insect, showing not merely an instinctive perception of distance, but an original ability to judge and to measure distance with something like infallible accuracy. A chicken was unhooded when nearly three days old. For six minutes it sat chirping and looking about it; at the end of that time it followed with its head and eyes the movements of a fly twelve inches distant, at twelve minutes it made a peck at its own toes, and the next instant it made a vigorous dart at the fly, which had come within reach of its neck, and seized and swallowed it at the first stroke; for seven minutes more it sat calling and looking about it. For about thirty minutes more it sat on the spot where its eyes had been unveiled without attempting to walk a step. It was then placed on rough ground within sight and call of a hen with a brood of about its own age. After standing chirping for about a minute, it started off towards the hen, displaying as keen a perception of the qualities of the outer world as it was ever likely to possess in after life. It never required to knock its head against a stone to discover that there was no road there. It leaped over the smaller obstacles that lay in its path and ran round the larger, reaching the mother in as straight a line as the nature of the ground would permit. This, let it be remembered, was the first time it had ever walked by sight."

In this experiment each movement of the chicken appears to have been started by an external stimulus. It pecked at the flies which it saw. It jumped or evaded the objects which it saw in its path. It remained stationary until its hereditary tendencies were stimulated by the sound and sight of the old hen in its neighbourhood.

Mr. Spalding again says:—"The art of scraping in search of food, which, if anything, might be acquired by imitation, is nevertheless another indubitable instinct. Without any opportunities of imitation, when kept quite isolated from their kind, chickens began to scrape when from two to six days old. Generally the condition of the ground was suggestive, but I have several times seen the first attempt, which consisted of a sort of nervous dance, made on a smooth table." Mr. Spalding, however, does not seem to have seen them scrape unless the ground was suggestive, and Dr. Allen Thompson hatched out some chickens on a carpet where he kept them for several days. They showed no inclination to scrape because the stimulus applied to their feet was of too novel a character to call into action their hereditary instinct; but when Dr. Thompson sprinkled a little gravel on the carpet and so supplied the appropriate or customary stimulus, the chickens immediately began their scraping movements. Here, again, we see the hereditary instinct requiring a local stimulus to bring it about.

Mr. Spalding again says:—"A young turkey, which I had adopted when chirping within the uncracked shell, was on the morning of the tenth day of its life eating a comfortable breakfast from my hand, when the young hawk in a cupboard ust behind us gave a shrill chip, chip, chip. Like an arrow the poor turkey shot to the other side of the room, stood there motionless and dumb with fear, until the hawk gave a second cry, when it darted out at the open door right to the extreme end of the passage, and there, silent and crouched in a corner, remained for ten minutes. Several times during the course of that day it again heard these alarming sounds, and in every instance with similar manifestations of fear." Generations of young turkeys must in their native home have had cause to dread the cry of birds of prey; and the hereditary lesson had been well learned.

A water-bird was reared from the egg by another observer. It would swim freely, but he could not get it to dive by any means which he tried. One day while watching it in the water, a dog suddenly appeared on the bank. The necessary stimulus was applied; the hereditary reflex was set in action, and in the twinkling of an eye the bird had dived.

Handed down from generation to generation as these instincts have been, and impressed upon their owners by the imperative law that failure to inherit an instinct or a reflex meant death to the degenerate, these reactions persist long after they have failed to be of use.

As Dr. Louis Robinson has pointed out, the horse roamed, in a wild state, over plains of more or less long grass and low bushes. When a horse is alarmed, he throws up his head to get as wide a view as possible. The cow on the other hand keeps her head low, as if to peer under the boughs which covered the marshy grass of her jungle home. The horse's chief danger lay when, as he approached a stream to drink, he was liable to be sprung upon by a lurking lion; and to this day the two things that a horse dreads most are the rustling in bushes or reeds by the road-side and the wheelbarrow or tree-stump which his imagination depicts as a crouching enemy.

The dog once formed his lair in rough stuff, and now, when approaching sleep gives the accustomed stimulus, our pet dogs turn round three times upon the hearthrug to smooth down imaginary grass stubs. As an instance of an instinct which by its persistence under altered circumstances has become actually prejudicial, I may give the case of some shore-birds which had for many years nested upon flats covered with pebbles. As long as the pebbles remained, the eggs, which closely resembled them in markings, were rendered inconspicuous, but as the sea receded and grass grew, the pebbles became few and far between. The birds still, however, kept to their haunt, and actually collected pebbles around their eggs, thereby rendering their nests the more conspicuous.

In domestic fowls the habit of cackling as soon as they have laid an egg would certainly be detrimental to a wild race, and Hudson makes some interesting remarks on the modified habit in a semiferal race. The Creolla fowls, descended through three hundred years from the fowls introduced by the early settlers in La Plata, are much persecuted by foxes, skunks, &c., ever on the look-out for their eggs or themselves. These fowls in summer always lived in small parties, each party composed of one cock and as many hens as he could collect—usually three or four. Each family occupied its own feeding-ground, where it would pass a greater portion of each day. The hen would nest at a considerable distance from the feeding-ground, sometimes as far as four or five hundred yards away.

After laying an egg she would quit the nest, not walking from it as other fowls do, but flying, the flight extending to a distance of from fifteen to about fifty yards; after which, still keeping silence, she would walk or run, until, arrived at the feeding-ground, she would begin to cackle. At once the cock, if within hearing, would utter a responsive cackle, whereupon she would run to him and cackle no more. Frequently the cackling call-note would not be uttered more than two or three times, sometimes only once, and in a much lower tone than in fowls of other breeds. If we may assume that these fowls in their long semi-independent existence in La Plata have reverted to the original instincts of the wild *Gallus bankiva*, we can see how advantageous the cackling instinct must be in enabling the hen in dense tropical jungles to rejoin the flock after laying an egg, while if there are egg-eating animals in the jungle intelligent enough to discover the meaning of such a short subdued cackle, they would still be unable to find the nest by going back on the bird's scent, since she flies from the nest in the first place! It is obvious that while this form of cackling is useful, excessive cackling would in a state of nature lead to its own suppression.

We may suppose that as the wild fowl became more and more closely domesticated the eggs of the greater cacklers were more rapidly found and preserved by their mistresses, and this tended to increase the tendency to cackle; while in the half-wild fowls of settlers who had plenty to do besides looking after their poultry, there was a gradual reversion to the wild type by the elimination of the eggs of loud cacklers when not rapidly retrieved.

Birds which nest within a short distance of the ground display, as a rule, great skill in concealing their nests, and are very conservative in type. How is it that one chaffinch's nest is so like another's?

Gregarious birds like rooks have opportunities for learning by imitation, and may thus have lost some of their spontaneous skill. I have read somewhere that, when rooks were introduced into the Antipodes, young birds having been selected for transportation, they were found, when the breeding season came round, to be at fault, and finally imitated the nest of some native bird; but chaffinches build apart from one another; how, then, do they get their nests so nearly alike? A great observer has suggested that this is due to recollection on the part of the nesting pair of the home in which they were reared. This explanation does not commend itself to my mind, and is refuted, if not by the instance of the rooks just quoted, by the fact that tame canaries hatched in a nest of felt will, when they themselves breed, use moss for the foundation of their nest, and hair as a lining, just as a wild bird would do, although, as they build in a box, the hair alone would be sufficient.

If you want examples of what pure instinct can do, go to the insect world. There you get them in infinite variety. Hatched from the egg long after the death of the mother, the majority of insects have to depend entirely on the duly ordered reaction of their nervous organisms to stimuli similar to those which have for ages incited their forerunners.

The bot of horses has been hatched from the egg inside the stomach of its host. After some nine months' residence in the intestines, it is passed with the fæces and subsequently becomes the bot-fly. Until it becomes a perfect insect it has never seen the outside of a horse, and yet, as soon as it sees one, it knows exactly where to deposit its eggs in a position from which they can be licked off and swallowed in their turn. The sight and perhaps the smell of the horse is sufficient to inspire the hereditary desire to deposit eggs in a particular spot. If the stimulus and its reaction were insufficient, that particular bot-fly would cease to propagate.

The garden spider, again, hatched from an egg laid the previous autumn, brings an enormous amount of hereditary skill into the vicissitudes of its life. It selects its site, builds its web, adapts it according to the most approved plans to fortuitous circumstances, and distinguishes between harmless flies and dangerous wasps with an innate cunning which is an exact replica of the actions of the last year's brood. The nest of the trapdoor spider, too, is quite as wonderful a production as the nest of any bird.

Caterpillars, when they have reached their full growth, display great skill in selecting appropriate hiding places in which to pass into the chrysalis form, and those which weave cocoons do so in recognised stages. Huber has described one which makes, by a succession of processes, a very complicated hammock for its metamorphosis; and he found that if he took a caterpillar which had completed its hammock up to say the sixth stage of construction, and put it into a hammock completed only to the third stage, the caterpillar did not seem puzzled, but completed the fourth, fifth, and sixth stages of construction. If, however, a caterpillar were taken out of a hammock made up, for instance, to the third stage, and put into one finished up to the ninth stage, so that much of its work was done for it, far from feeling the benefit of this, it was much embarrassed, and forced even to go over the already finished work, starting from the third stage which it had left off at, before it could complete its hammock. In this experiment it would appear that each instinctive action calls other actions in definite order, and unless the proper sequence is maintained the intelligence of the insect is unequal to bridging the gap.

Now let us apply the facts and inferences aforesaid to the nesting of the chaffinch. We have seen how habits acquired during the life-time of the individual impress themselves upon the nervous connections, until, when the accustomed stimulus is applied, they become quite independent of the will. We have seen how certain reflex phenomena which are necessary for the life of the individual have, through congenital connections, become so automatic, that they take place whether the brain is present or not. We have seen how habits of wild animals have, through similar nervous bonds, been handed down to tame descendants long after the said habits were useless and even detrimental. We have noted that ancestral habits may lie in abeyance until some perhaps unexpected stimulus arouses them—for instance, the scraping of chickens when placed upon gravel, or the diving of a water-bird upon sudden fright. We have ascertained that many of these instincts are certainly not due to instruction by older animals, but are purely spontaneous; that in insects these spontaneous actions are often most complicated, and are sometimes *not only* carried out in definite order, as in the weaving of their cocoons, but *cannot* be carried out except in that definite order.

The inference I draw is that the nest-building of the chaffinch is due to a succession of reflexes. You remember that when Alice was wandering about in Wonderland, she was continually coming upon medicine-bottles, marked "Drink me," or upon pieces of cake, marked "Eat me." You remember that when Alice obeyed these directions strange things happened. Alice was able to decipher her labels by the result of long and painful study in her nursery. Had they been written in the Cuneiform character, though perhaps perfectly intelligible to another, they would have conveyed nothing to her. The nervous system of the chaffinch has been educated by generations of hereditary experiences, and when the newly-wedded chaffinch pair start upon their housekeeping, they see in their mind's eye, upon some suitable site, a label marked "Build here"; they go through the stages of their architecture much as the caterpillar spins the different stages of its cocoon, each stage suggesting its successor; and each twig, hair, or feather which they use, bears upon it a label, "Use me next."

THE EDUCATION OF ENGINEERS.

SEVERAL papers on the training of engineers have recently come under our notice, and it seems worth while to bring together some of the expressions of views upon this important subject. It is difficult, if not impossible, to lay down any hard and fast line as to the course to be adopted by a youth who wishes to become a qualified engineer, for the way to follow must depend largely upon the position, age, prepotency and previous training of the aspirant. Assuming, however, that the principles of science have been studied at school, with practice in the physical laboratory, the question is, what is the next step to be taken? The answers to this are many and various, as will be gathered from the following notes from recent papers on the subject.

A paper on the training of electrical engineers, read by Dr. J. T. Nicolson before the Manchester section of the Institution of Electrical Engineers and published in the *Journal* of the Institution (May 1901, No. 150), with the discussion upon it, contains some noteworthy statements. The province of the laboratory in the scheme of electrical engineering is, Dr. Nicolson remarks, first to extend scientific knowledge by providing more experimental data; secondly, to show the student the scope, value and limitations of the theories he has studied in the class-room; and thirdly, to provide object-lessons on the general trend of electrical engineering design by means of machines and instruments of the newest types procurable.

Theory must not, however, be neglected. "Resting on a strong foundation of mathematics, physics and chemistry, the knowledge of the engineer must always include such pure sciences as those of kinematics, dynamics, hydrodynamics, thermodynamics and electrodynamics. A sound elementary acquaintance with all of these is necessary, and a specialised knowledge of that one more particularly useful to the engineer in his own branch must be obtained. It is, for instance, quite hopeless to try to explain to a man who has no knowledge of dynamics, upon what principles one proceeds in endeavouring to balance a locomotive. No amount of laboratory experiment will enable him to dispense with a knowledge of the mechanical principles involved. Again, the fundamental principles of thermodynamics may not be of much use in helping a man to fix the size of the cylinders of a steam engine; but they will, at all events, keep him from wasting his time in trying to design a perpetual-motion machine, and they will show him how far he can hope to go in the direction of the improvement of his heat motors, or other energy transformers." As Prof. Perry has said:—"An electrical engineer must have such a good mental grasp of the general scientific principles underlying his work that he is able to improve existing things and ways of using these things."

This latter qualification, a knowledge of theory, he must acquire by private study and from his college lectures; the former will be best inculcated by experimental work in the laboratory. In the electrical profession, considerable difference of opinion exists concerning the stage at which a youth should enter the works, if he is free to choose. Dr. Nicolson holds strongly the opinion that, after leaving school, the boy who intends to become an electrical engineer should first spend at least two years in the workshops of a *mechanical engineer.* Here he will learn the elements of smithing, moulding, pattern-making, fitting, machine-work and erecting. In this time he cannot help picking up the names and appearance of the common implements and processes fundamental to all kinds of engineering practice. Having put in two years in a mechanical engineering workshop, Dr. Nicolson thinks the student ought to enter an engineering college at about the age of eighteen, and he ought to study there for not less than three years.

"This last portion of his laboratory time should be devoted by our embryo electrical engineer to what is, in America, called 'thesis' work. This is of the nature of an experimental research, carried out either by the student himself or by a small group of students of which he is one. Very much valuable information has been obtained in American colleges in this way, regarding the various types of new apparatus continually coming out; and it is found that the students learn, in the course of such work, to assume responsibility by being in a large measure left to their resources. Such investigation usually requires either special apparatus or the loan of new types of machinery; but good work may also be got by making progressive tests of an operating plant either in the college or elsewhere."

In the discussion upon Dr. Nicolson's paper, the view that