are immediate and evident; it is believed that special cases of proportionality are involved in the general relation, and hence that Newton's Second Law is an *à priori* cognition.

But the cognition which his opponents affirm is a very different cognition, though this is an odd name to give to a mathematical doctrine. What his opponents affirm is that in certain cases forces measured in a certain way are proportional to their effects measured in a certain way; and by proportional they mean proportional and not something else. They affirm that experiment and observation are necessary to ascertain this proportionality; and that experiment and observation, and the method of verification, furnish overwhelming evidence in favour of the truth of Newton's laws. Their best proof is the *Nautical Almanac*, to those who can understand it and them.

I believe the *à priori* method to be as utterly barren in the future as it has been in the past. When a new truth has been discovered it is easy to say that it is evident *à priori*. Some day the laws of the actions of molecules and their relations to heat and electricity will be discovered by physicists; but I imagine they will be physicists of the type of Rumford and Faraday and Thomson and Maxwell. Meantime it is open to any *à priori* philosopher to anticipate the future.

And now, as far as I am concerned, this correspondence will cease. Mr. Collier is polite enough to say that my letter would have confirmed Sir W. Hamilton in his conviction that the narrow discipline of mathematics produces an incapacity for general reasoning; and he therefore cannot be anxious to continue a correspondence with one so contemptible, so stupid, and so ignorant as he plainly believes me to be.

A SENIOR WRANGLER

I SHALL be obliged if you will permit me to correct a verbal error, of some importance, in my letter (NATURE, vol. x. p. 84). The words "*finished conception*," in col. 2, line 26, should be "*finished pre-conception*."

J. COLLIER

The Glacial Period

BOTH Mr. Belt and Mr. Bonney, have, I think, missed the one point on which the question under discussion turns. The shell-bearing drift-gravels are *well stratified*. I can speak to those in the neighbourhood of Macclesfield, which run up to 1,100 ft. above the sea, being also very delicately current-laminated. I am puzzled to imagine how this structure could be obtained if the gravels were brought to their present position in the way Mr. Belt supposes; indeed its presence seems to me fatal to his hypothesis. It is not the case moreover that all the shells are smashed and scratched. At Macclesfield most of the shells are broken, as one would expect to be the case if they had been tossed about on a shingle-beach; but entire specimens were not very rare. As for scratches, I never saw one on either the shells or the pebbles of these gravels; in the boulder clay, where the included stones are scratched, scratches are occasionally seen on the shells as well.

A. H. GREEN

Cockermouth, June 6

VENUS'S FLY-TRAP (*Dionæa muscipula*) *

THERE are two ways of studying a plant or an animal. One of these consists in the mere contemplation and description of its external aspects and behaviour. Persons who occupy themselves with this sort of study are commonly called naturalists; for it is by them that by far the greater proportion of the facts we possess relating to natural objects has been gained.

But there is another and a much better sense in which a man may be said to be a naturalist. The true naturalist does not content himself with standing at one side and watching the proceedings of nature as a mere spectator. Animated by that insatiable scientific curiosity from which some shrink, in the fear lest it should carry them too far, while the greater part are indifferent, he occupies his whole life in seeking to lift the veil from all that is hidden in nature and in discovering and exposing the springs of every secret process. His restless spirit cannot content itself with contemplation of the mere external aspects of living beings nor even with the most minute and searching study of the forms and structure of organic life. For even if he begin as a botanist or zoographist, a mere describer of plants or animals, he is forced by the perception of that general adaptation of means to ends and ends to means which he sees everywhere, to become first an anatomist then a physiologist. The study of these external aspects leads him, if possessed of that curiosity which is his characteristic attribute, to study their minute structure, and this, the further he goes into it, stirs up in him the desire to penetrate further into the mysteries of their being. For the delight and interest with which the forms, colours, and structure of animals and plants fill us is derived from the conscious or unconscious perception by our minds of their *adaptation*—their fitness for the place they are intended to occupy. I would go further even than this, and maintain that our artistic perception of beauty in nature is, I believe, in great measure derived from the same source.

But to understand nature in the sense of the naturalist we must know not only those aspects which she is willing to present to us but those she is determined to hide. For this end, when we cannot get at what we want by persuasion, we are often obliged to use compulsion.

It is constantly happening to the naturalist, that he has a process, a contrivance before him, a series of phenomena the connection or evolution of which he cannot understand. He stands at one side and watches and learns but little, for nature refuses to tell *why* she does this, or *how* that. Under these circumstances, which recur, not once in a way, but daily and hourly in the study of plant and animal life, what is he to do? Is it his duty to sit down respectfully and wait, in the hope that what is now difficult and obscure may, by the light thrown upon it from right or left, become more or less clear and intelligible? No. This is not the spirit of the naturalist. If nature conceals the truth, we frankly deny her right to do so, and wrest it from her by force. If circumstances are unfavourable, we alter them to suit our ends. If, as repeatedly happens, a number of antecedents are seen to lead to one event, if a number of apparent causes conspire to one result, we proceed in our investigation by taking away first one, then others of these antecedents, until by a succession of trials (or as they are commonly called experiments) we find the true one, viz. that of which the removal or modification abolishes or alters the event. It is thus, and thus alone, that we compel nature to tell "that wherein her great strength lies."

It is my purpose in this lecture to illustrate to you if I can, by an example, that the systematic application of the method of experiment is the only method by which it is possible to become so acquainted with the forces of nature as eventually to be able to convert them to useful purposes (and this is one, though by no means the highest, end of natural knowledge). More particularly is it true of that branch of natural knowledge which *par excellence* we call physiology, that it is by experiment alone that progress has been or can be made; the whole subject being in its present state but a system of experimental results.

A while ago I applied the term forcible to this method because it is the plan by which, as Bacon said, we torture nature. But let us remember that this is a mere figure of speech. In disciplining nature to our ends, in forcing her to give up her secrets, we use no violence, but utmost gentleness. Plant or animal, to be made to tell its story, must be delicately handled, so delicately that, by association, the very care which the naturalist, for scientific ends, bestows on animals and plants, unavoidably engenders a love for them. However right and necessary it may be that we should to-night destroy and mangle these beautiful leaves for our own pleasure and instruction, let us not do so recklessly, for the life and beauty we destroy we cannot with all our science bring back again or imitate.

The name *Dionæa muscipula* was given to the plant when it was first imported from America. It belongs to the family Droseraceæ, a very natural one, *i.e.* one in

* Lecture by Dr. Burdon Sanderson, F.R.S., at the Royal Institution, Friday evening, June 5, 1874.

which the family characteristics are so well marked that in no individual member of it can the signs of original relationship be mistaken.

In speaking of original relationship, I refer rather to that of descent or ancestry than to community of parentage. Thus in this order we have distinct evidence that in the Drosophyllums, Droseras, Dionæas, which constitute the family, the peculiarities which they have in common and by which they are distinguished from other plants are not possessed by them in equal development and completeness, so that here as elsewhere the more developed forms stand to the less perfect ones rather in the relation of descendants than in that of cousins.

In the Droseraceæ the most striking peculiarity is one which is entirely functional or even teleological. It consists in this, that each member of it possesses in one way or other adaptedness to one and the same end. This end is the catching of insects, and not only catching them but digesting them, using them as food in short, just as animals do. These animal endowments, which have for some years engaged the attention of our great naturalist, are possessed (as we hope he will some day show us) by each individual species in a degree which, in the main, corresponds to the general development of the plant; so that each advance from less to more perfect form and structure is accompanied by an improvement in its adaptedness to the function of preying upon insects.

Description of the Plant.—Of root and flowers I need say little or nothing. It is the leaf to which I have to ask your attention. It is of very peculiar form. The blade of the leaf consists of two nearly semicircular halves or lobes, which are united together along their straight borders by a strong mid-rib. On to this the two lobes are set in planes which are nearly at right angles to each other. The curved outer edge of each lobe is strengthened by a thickened border or hem. From the hem spring some twenty spikes on either side, which are directed upwards and inwards. The under surface is bright green, smooth and glistening, and is marked with parallel streaks. The upper surface is pink or red, and is beset with little red projections, which are called glands.

In addition to these glands there are on the upper surface of each lobe of the leaf three spines, which are of extreme delicacy and are always arranged as if at the angles of a triangle, about the middle of the lobe. The petiole or leaf-stalk is of the shape of the handle of a tea-spoon, the only difference being that its upper surface is channelled along the middle instead of being flat. At its end it is united to the leaf by a jointed isthmus, of about a line in length and breadth.

The mechanism by which the leaf catches insects is strikingly like that of a rat trap. When it is open the lobes are, as I have said, at right angles to each other. When an insect comes into contact with either, at once they approach each other, but this does not occur with the suddenness and completeness that it occurs in the rat trap. The lobes begin to close sharply enough, but do not come quite together, remaining for some time *entr'ouvert*. When the leaf is in this state of half closure, it is easy to see what is the significance of the two sets of prongs already mentioned. You see that they are set on alternately along the opposite edges of the lobes, so that just like the teeth of the rat trap they fit into each other. It is not difficult to see why this is, *i.e.* why the spikes are arranged alternately. The leaf, being a trap, is made like a trap. But I should not have been able to tell you why the leaf does not at once close on its prey had not Mr. Darwin told me. After having partially closed, as I have said, one of two things may happen. The insect, having been caught, at once begins to think of escaping, and makes efforts to do so, which may or may not be successful. If it is small, it easily finds its way out through this wonderful grating formed by the crossing of the teeth; and in this case the leaf soon recovers, expands again, and is ready for the capture of another victim. If it is large all its efforts to regain its liberty are futile. Repelled by its prison bars, it is driven back upon the sensitive hairs, which stick into the interior of its cell, and again irritates them. By doing so, it occasions a second and more vigorous contraction of the lobes. The result is that the creature is not only captured, but crushed; not only swallowed, but, as I have already said, digested.

In all this we see a wonderful completeness of adaptation for a purpose; but I fancy that the purpose itself would be considered unworthy or even immoral by some persons. Just as in the "gentle craft" the small fry are rejected and thrown back again into the water to enjoy a little more life and to be better prepared for their future destiny, so the plant, not quite for the same reason, acts in a similar manner. The angler rejects the small fish with a view to their future and his own, for he wants them to grow larger that he may have the better sport out of them afterwards; but the plant lets the little insects go, because it would cost too much to keep them; and this leads me to the description of what happens to the leaf and to the poor fly when it is big enough for the leaf to find it worth while capturing, *i.e.* when it is too big to slip through the bars.

Digestion of Dionæa.—Even after slight irritation, such as that which is produced when a fly merely touches one of the sensitive hairs, or when they are touched with a dry camel-hair pencil, the leaf remains closed for some time, usually more than twenty-four hours. But if a fly is caught, or any other nutritious substance is introduced, the case is different. For a week or more the leaf remains closed on its prey, the two lobes being at first pressed flat against each other. The two lobes indeed close round the fly so completely that its body gives rise to two projections of the (outer) surface of each lobe, which correspond to it in form. The result of this is that the secreting glands on the part of the leaf against which the body of the fly presses are irritated, and begin to pour out a quantity of secretion. Gradually this effect extends to the rest of the leaf, and consequently its cavity becomes gradually extended.

The meaning of this bulging is that the fly is becoming digested. The liquid juice which the glands pour out has the property of so acting on the tissue of the fly's body that they at first become diffluent and then are absorbed.

When we call this process "digestion" we have a definite meaning. We mean that it is of the same nature as that by which we ourselves, and the higher animals in general, convert the food they have swallowed into a form and condition suitable to be absorbed, and thus available for the maintenance of bodily life.

The nature of animal digestion is best explained by examples. If I take some starch, which is not soluble, and put it into my mouth, and keep it there for a certain time, it has become first soluble, and finally transformed into a substance quite different in properties. If we examine into this process we find that the change of starch into sugar takes place, because there exists in saliva a ferment called ptyaline. We know that it is the ptyaline which does the work, because if we separate this substance in a solid state, then dissolve it in water in which starch is diffused, the starch is converted into sugar. We call it a ferment, for two reasons—first, because, like leaven, it acts in small quantity, a mere trace being sufficient; and secondly, because it does not itself take part in the transformation. This is one example, and a very simple one; but it is not with this that we compare the digestion of Dionæa, but with that which in man and animals we call digestion proper, the process by whch the nitrogenous constituents of food are rendered fit for absorption. This takes place, not in the mouth, but in the stomach. It also is a fermentation, *i.e.* a chemical change effected by the agency of a leaven or ferment which is contained in the stomach-juice, and can be, like the ferment of saliva, easily separated and prepared. As so separated, it is called pepsin (the medicine called by that name is supposed to contain some of it, and indeed often does). Consequently, having the ferment, we can easily imitate digestion out of the body. For this experiment there are three things necessary—first, that our liquid should contain pepsin; secondly, that it should be slightly acid; and thirdly, that it should be kept at the temperature of incubation, *i.e.* about 97° F. We select for the experiment a substance which, although nutritious and containing nitrogen, is not easily digested—such, for example, as boiled white of egg. In water containing a small percentage of hydrochloric acid and a trace of pepsin, it is gradually dissolved; but chemical examination of the liquid shows us that it has not been destroyed, but merely transformed into a new substance, called peptone, which is afterwards absorbed, *i.e.* taken into the circulating blood.

Between this process and the digestion of the Dionæa leaf, the resemblance, as Mr. Darwin has found by a most elaborate comparative investigation, is complete. It digests exactly the same substances in exactly the same way, *i.e.* it digests the albuminous constituents of the bodies of animals just as we digest them. In both instances it is essential that the body to be digested should be steeped in a liquid, which in Dionæa is secreted by the red glands on the upper surface of the leaf; in the other case, by the glands of the mucous membrane. In both the act of secretion is excited by the presence of the substance to be digested. In the leaf, just as in the stomach, the secretion is not poured out unless there is something nutritious contained in it for it to act upon, and finally in both cases the secretion is acid. As regards the stomach, we know what the acid is: it is hydrochloric acid. As regards the leaf, we do not know precisely as yet, but Mr. Darwin has been able to arrive at very probable conclusions, the setting forth of which we look forward to in his expected work on the Droseraceæ.

(*To be continued.*)

REPORT OF PROF. PARKER'S HUNTERIAN LECTURES "ON THE STRUCTURE AND DEVELOPMENT OF THE VERTEBRATE SKULL" *

IV.

In the Teleostei the jaws attain their maximum amount of mobility, and the articulation of the lower jaw is, consequently, brought to the farthest possible distance from the skull, by the disjointing of the mandibular arch from its original attachment. This arch consists of two cartilaginous bars (see Fig. 11, Pl.Pt and Mck) corresponding to the upper and lower jaws of the shark or ray, but containing certain important ossifications. The apex of the arch, corresponding to the spiracular cartilage of the ray, is formed by the meta-pterygoid (Fig. 7, M.Pt), below which, and separated from it by a broad synchondrosis, is the quadrate (Qu) bearing a rounded articular surface for the mandible. In the pterygo-palatine cartilage are three ossifications—the palatine (Pl), pterygoid (hidden in the figure by the maxilla and jugal), and mesopterygoid (Ms.Pt). The proximal portion of the originally cartilaginous lower jaw is ossified by the articular (Art), while its distal portion remains as the comparatively slender Meckel's cartilage, running on the inner side of the dentary, almost to the symphysis.

As in the Elamobranchs, the proximal part of the hyoid arch forms the suspensory apparatus for the jaws, but unlike the corresponding cartilage in those fish, contains two ossifications, the large and massive hyo-mandibular (H.M), articulating with a cartilaginous surface afforded to it by the sphenotic and pterotic (see Fig. 9), and the symplectic (Sy) below, which, fitting into a groove in the quadrate, firmly binds together the hyoid and mandibular arches. The free portion of the hyoid articulates with the cartilaginous space between the hyo-mandibular and symplectic, through the intermediation of a small bone (shown in Fig. 7 by dotted lines, being hidden by the pre-opercular), called by Cuvier the stylo-hyal, but better named inter-hyal, as it is not the homologue of the mammalian styloid process. The hyoid cornu is segmented as in the ray, except for the fact that there is a median basal piece, usually called, from the circumstance of its giving support to the tongue, glosso-hyal (G.Hy). All these segments are ossified and separated from one another by tracts of cartilage.

The branchial arches are much smaller in proportion to the mandibular and hyoid than in the shark and ray; they also lie almost entirely within the latter, instead of in a regular series behind it. Each of the first four bars is divided into pharyngo-, epi-, cerato-, hypo-, and basibranchial; and each segment, with the exception of the last pharyngo-branchial, is ossified. The fifth arch (inferior pharyngeal bone) is much smaller than its predecessors, and consists simply of a tooth-bearing cerato-branchial. The pharyngo-branchials (superior pharyngeal bones) are not dentigerous.

The development of the salmon was described at far greater length than that of the shark or ray, the metamorphoses gone through being much more complex, and exhibiting in a most instructive manner the endless modifications which the facial arches may undergo in their modes of segmentation and coalescence.

Besides the adult, seven arbitrary stages of the skull were described; in the first three of which the embryo was still unhatched, and lying as a flat tape-like band about $\frac{3}{4}$ of an inch long coiled round the yelk-sac; in the fourth the head was just emerging from the chorion; the fifth consisted of salmon fry at the second week after hatching; those of the sixth stage were at the sixth week; and those of the seventh young salmon of the first summer, varying in length from $1\frac{1}{2}$ to $2\frac{1}{4}$ inches, and having in all essential respects the cranial characters of the adult. The earliest stages are remarkable for their want of symmetry, the head being so twisted that only one eye is visible in an upper view.

The head of an embryo at the first of these stages is shown in Fig. 10; it resembles very closely the earliest conditions in the shark and ray (Figs. 3 and 6, vol. ix. p. 467), having, like them, prominent sense-capsules, a widely-open mouth, and simple, unsegmented facial arches, which latter, however, present very important differences to the homologous structures in the lower types. The trabeculæ (Tr) are seen in the roof of the mouth, where they lie, enclosing the pituitary body (Pty) like a pair of forceps, in the same plane as the investing mass and notochord, and not at right angles to them like the postoral arches. Curving under the eye is a bar of somewhat thickened indifferent tissue (Pl.Pt) representing the pterygo-palatine arcade, but, even in this extremely early stage, so entirely distinct from the mandibular arch proper (Mn) as to have the appearance of a true, separate face-bar. It long remains, however, in a rudimentary state as regards histological development, not being converted into true hyaline cartilage until the fourth stage, when it unites with the main part of the mandibular arch.

In the second stage, a most noticeable change has taken place with regard to the hyoid. A lozenge-shaped basal piece, the glosso-hyal, has appeared between the bars of opposite sides, and the whole arch has split lengthwise from top to bottom, becoming divided into an anterior and posterior division, the former of which becomes the fixed hyo-mandibular and symplectic, the latter the free epi- and cerato-hyals.

In the third stage, this process has gone farther: the two divisions of the hyoid have become separated from

* Continued from p. 10.