

extent, that these variations alone cannot be taken to mark distinct species.

Most of these conclusions are fully supported by Prof. Temminck, from an examination of the very extensive series of specimens in the Leyden Museum, though, from not possessing specimens of the smaller male, he was unable to detect any specific difference in the females.

Prof. Owen, in his admirable papers published in the 'Transactions of the Zoological Society,' has described the apparent confusion in the position of the second set of teeth in the jaws of the young animal, and observes that it seems wonderful that they should all fall into their proper places in the adult, without those irregularities which are so frequent in Man. My specimens however prove that such irregularities are very frequent, as more than one-half of my crania exhibit them in a greater or less degree. In two cases a sixth molar tooth occurs on one or both sides of the jaw; the incisors are often unsymmetrical and the whole jaw is frequently oblique, in one case so much so, that while the upper canine closes inside the lower on one side of the jaw, it is outside on the other.

A striking peculiarity, not, I believe, hitherto noticed, exists in the mammæ of the female, which are scarcely perceptible even when giving suck. In two specimens which I shot with their infant young, the nipples rose from a breast not more developed than in the male animal.

The preceding observations might have been very much extended, but the object has been merely to give some account of the writer's observations and collections, believing that no definite and certain conclusions can be arrived at without a comparison of his materials with those which already exist in England and at Leyden, a comparison which he looks forward to making on his return.

Sarawak, Dec. 1855.

XLVI.—*On Prof. Huxley's attempted Refutation of Cuvier's Laws of Correlation, in the Reconstruction of extinct Vertebrate Forms.* By H. FALCONER, M.D., F.R.S. &c.

THE printed Proceedings of the Royal Institution contain a full abstract of the principal part of an evening lecture, delivered by Prof. Huxley, on the 15th February last, "On Natural History, as Knowledge, Discipline, and Power," authenticated with his initials, and thus leaving no doubts as to the authorship. It contains some statements which are so remarkable,—emanating

from one who is at the same time a Professor of Physiology, and an officer on the palæontological staff of the Museum of Economic Geology,—as to require some notice.

The temptations of a popular lecture are notoriously so great, to produce effect instead of merely giving instruction, and to heighten sober fact with a little gilding, that a considerable allowance is usually extended to discourses addressed to large mixed audiences. If the banquet is plain, to go down well, it requires some strong seasoning. But there is a limit to this kind of consideration; and when a man of science, of recognized standing, assails generally admitted principles and established reputations, in a discourse of this nature, which comes before the world in the permanent form of publication, it is no longer entitled to indulgence, but becomes a fair subject of legitimate criticism.

Nearly three-fourths of Mr. Huxley's abstract are devoted to the first head, viz. Natural History regarded as *knowledge*, the leading feature of which is an attempt to refute the principle propounded by Cuvier, that the laws of correlation which preside over the organization of animals, guided him in his reconstruction of extinct forms. It is to this part of the lecture that the remarks now offered have reference.

By the common verdict of mankind, George Cuvier has been considered one of the most successful investigators of natural knowledge, in all time. His principal claim for this rank rests upon his having been the founder and architect of philosophical palæontology. He not only laid the first stone, but he constructed, and covered over, the edifice. What has been accomplished by his successors, has been merely to fill up, and embellish the details of the interior; this much he left to them as an express legacy. The general results of his researches, and the principles upon which they were conducted, were set forth in the "*Discours préliminaire*," which, taking due account of the state of knowledge at the time, and the wide scope of the argument, has hitherto been held up as a model of exhaustive philosophical inquiry, conveyed in a strain of chastened didactic eloquence, such as has not yet been surpassed in the literature of natural history.

That in some important respects Cuvier was behind the progress of zoological science in his day, is undeniable; as also that he arrived at some wrong palæontological conclusions. This is not to be wondered at; the real marvel being, that in achieving so much in a new field, he erred so little. But Mr. Huxley assails him on very different and much higher grounds. "The prince of modern naturalists," it is alleged, "did not himself understand the methods by which he arrived at his great re-

sults." "His master-mind misconceived its own processes." "Whatever Cuvier himself may say, or others repeat, it seems quite clear that the principle of his restorations was *not* that of the physiological correlation or coadaptation of organs."

Such strong assertion should be well supported; for, besides the attack upon Cuvier and his followers, the very foundations of palæontology, as they have hitherto been understood, are assailed. Let us now see whether soundly or otherwise. Mr. Huxley, after showing up the pretensions and shortcomings of the alleged philosophical principle, supplies the blank with a substitute of his own, namely, "A law of the invariable coincidence of certain organic peculiarities established by induction;" or, in other words (when the definition and illustrative cases are analysed), empirical observation. In order to put the case fairly, and guard against the risk of misapprehension, a long extract must be made:—

* * * "Is this utilitarian adaptation to a benevolent purpose, the chief, or even the leading feature of that great shadow, or, we should more rightly say, of that vast archetype of the human mind, which everywhere looms upon us through nature? The reply of natural history is clearly in the negative. She tells us that utilitarian adaptation to purpose is not the greatest principle worked out in nature, and that its value, even as an instrument of research, has been enormously overrated.

"How is it then, that not only in popular works, but in the writings of men of deservedly high authority, we find the opposite dogma—that the principle of adaptation of means to ends is the great instrument of research in natural history—enunciated as an axiom? If we trace out the doctrine to its fountain-head, we shall find that it was primarily put forth by Cuvier, the prince of modern naturalists. Is it to be supposed then that Cuvier did not himself understand the methods by which he arrived at his great results? that his master-mind misconceived its own processes? This conclusion appears to be not a little presumptuous; but if the following arguments be justly reasoned out, it is correct:—

"In the famous 'Discours sur les Révolutions de la Surface du Globe,' after speaking of the difficulties in the way of the restoration of vertebrate fossils, Cuvier goes on to say:—

"Happily, comparative anatomy possesses a principle whose just development is sufficient to dissipate all difficulties; it is that of the correlation of forms in organized beings, by means of which every kind of organized being might, strictly speaking, be recognized, by a fragment of any of its parts.

"Every organized being constitutes a whole, a single and complete system, whose parts mutually correspond and concur,

by their reciprocal reaction to the same definitive end. None of these parts can be changed without affecting the others; and consequently each taken separately indicates and gives all the rest.'

"After this, Cuvier gives his well-known examples of the correlation of the parts of a Carnivore, too long for extract, and of which therefore his summation merely will be given:—

"In a word, the form of the tooth involves that of the condyle; that of the shoulder-blade; that of the claws: just as the equation of a curve involves all its properties. And just as by taking each property separately, and making it the base of a separate equation, we should obtain both the ordinary equation and all other properties whatsoever which it possesses; so, in the same way, the claw, the scapula, the condyle, the femur, and all the other bones taken separately, will give the tooth, or one another; and by commencing with any one, he who had a rational conception of the laws of the organic œconomy, could reconstruct the whole animal.'

"Thus far Cuvier; and thus far, and no further, it seems that the compilers, and copiers, and popularizers, and *id genus omne*, proceed in the study of him. And so it is handed down from book to book, that all Cuvier's restorations of extinct animals were effected by means of the principle of the physiological correlation of organs.

"Now let us examine this principle; taking, in the first place, one of Cuvier's own arguments and analysing it; and in the second place, bringing other considerations to bear.

"Cuvier says—'It is readily intelligible that Ungulate animals must all be herbivorous, since they possess no means of seizing a prey (1). We see very easily also, that the only use of their fore-feet being to support their bodies, they have no need of so strongly formed a shoulder; whence follows the absence of clavicles (2) and acromion, and the narrowness of the scapula. No longer having any need to turn their fore-arm, the radius will be united with the ulna, or at least articulated by a ginglymus and not arthrodiially with the humerus (3). Their herbivorous diet will require teeth with flat crowns to bruise up the grain and herbage; these crowns must needs be unequal, and to this end enamel must alternate with bony matter (4): such a kind of crown requiring horizontal movements for trituration, the condyle of the jaw must not form so close a hinge as in the Carnivora; it must be flattened; and this entails a correspondingly flattened temporal facet. The temporal fossa which will have to receive only a small temporal muscle will be shallow and narrow (5).'

"The various propositions are here marked with numbers, to

avoid repetition ; and it is easy to show that not one is really based on a necessary physiological law :—

“(1.) Why should not ungulate animals be carrion-feeders ? or even, if living animals were their prey, surely a horse could run down and destroy other animals with at least as much ease as a wolf.

“(2, 3.) But what purpose, save support, is subserved by the fore-legs of the Dog and Wolf ? how large are their clavicles ? how much power have they of rotating the fore-arm ? (4, 5.) The Sloth is purely herbivorous, but its teeth present no trace of any such alternation of substance.

“Again, what difference exists in structure of tooth, in the shape of the condyle of the jaw, and in that of the temporal fossa, between the herbivorous and carnivorous Bears ? If Bears were only known to exist in the fossil state, would any anatomist venture to conclude from the skull and teeth alone, that the white bear is naturally carnivorous, while the brown bear is naturally frugivorous ? Assuredly not ; and thus, in the case of Cuvier's own selection, we see that his arguments are absolutely devoid of conclusive force.”

Our first remark is, where and by whom has the principle of the “*utilitarian* adaptation to purpose*” been used as an instrument of research ? Mr. Huxley avers that its value as such has been enormously overrated ! If so, by whom has it been ever used ? From the prevalence of adaptations and mechanisms in nature, suited to the production of certain ends, we reason up to the agency of an all-wise, powerful and benevolent Designer. But the inference is a product, not an *instrument* of the research ; and to call it the latter, is simply a misuse of terms.

The same objection applies to what Mr. Huxley designates as “the opposite dogma—that the principle of adaptation of means to ends is the great instrument of research in natural history.” The generalization in this case also is a *result*, not an *instrument*, of the research.

Mr. Huxley contrasts the two as opposite dogmas. Wherein, we would ask, lies the opposition ? Hot and cold, dry and moist, sweet and sour, are in ordinary language opposites ; and in medicine, theorists speak of the *opposite dogmas* of the humoral and mechanical, the chemical and vital pathologies. They are obviously opposed, because the one is inconsistent with, and of a contrary nature to, the other. But there is nothing of like opposition and incompatibility in the two dogmas or principles as enunciated by Mr. Huxley. So far from such being the case, the first is merely a more advanced stage of the second. In the

* The employment of the term in this sense is by Mr. Huxley.

one, we satisfy ourselves by observation of the necessary correlation of the parts to effect a common end; in the other, we speculate from these premises, as to whether or no they furnish proofs of a Supreme Designer. We may stop short at the former stage without going further; but we cannot arrive at the second without having gone through the first. The two principles, therefore, have never been employed as instruments of research in natural history, nor are they, in their nature, opposites.

In disquisitions of this kind, precision of thought and expression is so essential, that it seemed necessary to clear the ground of these preliminary objections, before coming to the gist of Mr. Huxley's argument, namely, that the law of reciprocal relation between the organs of animals is *not* the principle which guided Cuvier in his reconstruction of extinct forms.

Mr. Huxley first takes the beautiful illustration given by Cuvier, of the correlation of the parts in a Carnivore, quoting the summary; and he attempts to refute it by asking, "What difference exists in the structure of tooth, in the shape of the condyle of the jaw, and in that of the temporal fossa, between the herbivorous and carnivorous Bears? If Bears were only known to exist in the fossil state, would any anatomist venture to conclude, from the skull and teeth alone, that the white bear is naturally carnivorous, while the brown bear is naturally frugivorous? Assuredly not; and thus in the case of Cuvier's own selection, we see that his arguments are absolutely devoid of conclusive force."

Can it be believed, after this, that the case in question is *not* that of Cuvier's selection? But such is really the fact. In stating the proposition to be demonstrated, Cuvier puts it thus: "If the intestines of an animal are organized so as *only* to digest flesh, and the flesh fresh," then these correlative conditions are involved, viz.: its jaws must be constructed to devour a prey; its claws to seize and tear it asunder; its teeth to cut it up and divide it; its organs of motion to pursue and catch it; its organs of sense to recognize it at a distance; and it must also be endowed with the instinct to conceal itself and lay toils for its victims. "Such will be the conditions of the carnivorous habit; every animal destined for such habit will infallibly have them in combination, for its race could not subsist without them." But the Bears have *not* their "intestines organized *only* to digest fresh flesh;" nor their claws to seize a prey and tear it asunder; nor their teeth only to cut up and divide it; nor their organs of motion to pursue and catch it; nor have they the instinct to conceal themselves and entrap it. What was obviously in Cuvier's mind was, a pure typical digitigrade carnivore like the Tiger, which rigidly fulfils the terms of the proposition, and

every one of the conditions set forth as involved in it. The Bears are heavy cumbrous animals; their teeth are not purely carnivorous, but mixed*; their feet are plantigrade; and their habit of diet, when they are regarded in the mass, is omnivorous. We have known the same species, a brown bear, to browse on young grass like an ox; to devour the flesh of a slaughtered deer left in the forest; and to kill and eat a tame pheasant that came within its reach. Nature has given mixed teeth, and a mixed organization throughout, to match the mixed habits of the genus. Technically they are ranked, in some classifications, as among the Carnivora; but competent naturalists divide the order of *Fera* into three groups, excluding the Bears and their allies, under the designation of *Plantigrada*, from the *Carnivora*, which comprise the *digitigrade* Dogs, Cats, Hyænas, &c. How then is Mr. Huxley warranted in asserting, that the Bears were "the case of Cuvier's own selection"? In every demonstration of a subject, and in ordinary instruction, we select the simplest problems; and having mastered them, we next proceed to the more complicated or mixed. Cuvier took the pure and simple case: Mr. Huxley fixes upon him the mixed.

Let us now take the case as put by Mr. Huxley, and suppose that the brown and white bears were only met with in the fossil state; but with the proviso of the other living species being known to us as at present. The comparative anatomist would, we believe, be led to infer that the polar bear had been more carnivorous than the brown bear, and the latter more of a vegetable feeder than the former. The polar bear differs more from all the other bears in the form of the skull, than these do from one another; and the differences are all in the direction of a more carnassial type. In proof that this is not a rash or unguarded assertion, it can be shown that comparative anatomists have not hesitated, in the cases of certain extinct fossil bears, to form conclusions as to their habits of diet upon the osteological evidence. Thus: "From the greater proportional size and more complicated tubercular surface of the posterior molar teeth, especially in the upper jaw, and from the greater complication on the crown of the smallest persistent molar in the lower jaw, one might be led to suppose that the *Ursus spelæus* fed more on vegetables than the grisly bear does" (Owen, Brit. Foss. Mamm. p. 101). The evidence furnished by the skull confirms this guarded inference: it deviates widely in form from that of the polar bear. Again: "The above remarkable modification of the crowns of the molar teeth of the lower jaw, indicates this great extinct bear (of the Sewalik Hills) to have been more car-

* Their molar teeth generally manifest in both jaws a tuberculate grinding surface. Owen, *Odontog.* vol. i. p. 501.

nassial than the *Ursus spelæus*, or any of its existing congeners" (Owen, *Odontography*, vol. i. p. 501). The same conclusion had been previously arrived at by the original describers of this species, from the combined indications of the skull and teeth*. Here then are two fossil bears, the one of which is inferred to have been more of a vegetable feeder, and the other more carnivorous, from characters of correlation presented by their skulls and teeth;—being practical refutations of the assertion made by Mr. Huxley. It is true that the legitimacy of the deductions may be questioned or denied: all that can be said in reply is, that if the propositions, positive and negative, are considered according to the degree of their respective probability, the verdict of every competent judge will be in favour of the former. Of more than this, a case of the kind does not admit.

Mr. Huxley next takes in hand the opposite case of the *Ungulate Herbivora*, as put by Cuvier. They present the simplest and most unmixed types of the strictly vegetable feeders, and their organization is modified throughout, in a series of adaptations in contrast with those presented by the *Digitigrade Carnivora*, and in necessary correlation with each other (i. e. *necessary* in the sense of being demonstrable in such a way that the contrary involves an absurdity and is inconceivable). We will take Mr. Huxley's objections in the order suggested by the analysis. Cuvier states that: "Their herbivorous habit will require teeth with flat crowns to bruise up the grain and herbage; this crown must needs be unequal, and to this end enamel must alternate with the bony materials." Mr. Huxley attempts to refute the generality of the proposition by the case of the Sloth. He says, "The Sloth is purely herbivorous, but its teeth present no trace of any such alternation of substance." It will be shown in the sequel, that they *do* present such alternation; but the first remark that is suggested is, that in an argument where there is an express specification of the premises, it is inadmissible to adduce a case that does not come within the terms. Cuvier specifies the *Ungulata* (including the *Pachydermata*, *Solidungula*, and *Ruminantia*): Mr. Huxley meets him with the Sloth, which, although herbivorous, does not belong to either, but to the order *Bruta*, comprising animals very different in their habits and organization from the *Ungulata*. The mass of the species in the one order is constructed for extreme speed, to escape from their predaceous enemies; while the progression of the mass in the other is extremely slow, but strictly in unison with their habits and wants. Instead of presenting *a narrow scapula, with no acromion and no clavicle* (conditions expressly specified by

* Asiatic Researches, vol. xix. p. 200.

Cuvier), the Sloth has a *very broad scapula, an enormously prolonged acromion, and a clavicle*. A portion of the functions of its fore-arm is modified after the plan presented by the Tiger, instead of that of the *Ungulata*. The habits of the Sloth, although herbivorous, required it, and the *necessity* under the law of correlation worked out the means*. The detailed demonstration would be tedious; but it is wholly unnecessary, as every comparative anatomist is familiarly acquainted with it, and probably no one better than Mr. Huxley. So far as the applicability of this objection to the case in point is concerned, it is clearly of a still more exceptionable character than that of the Bears *contra* the typical Carnivora.

But the special force of Mr. Huxley's objection lies in the absence of enamel from the teeth of the herbivorous Sloth. The adduction of the instance is ingenious; yet the objection in reality is more specious than valid. The molars of the Sloth consist of an irregular cylinder of soft and open-grained ivory (vascular dentine of Owen), which is so permeated by vascular or medullary canals, that it has been compared structurally to the teeth of certain fishes; this central mass is encased in a shell of compact hard ivory (unvascular dentine of Owen), closely resembling (it is said) that of the human tooth†; and outside of this shell there is a layer of cement harder than the central mass, but softer than the shell of ivory. The cement by use wears away, so as "to form a bevelled edge," while the central mass becomes depressed, the edge of the shell projecting between them. The crown thus presents *three alternate materials of unequal hardness*, resulting in an unequally worn surface, being the very end to be attained, in the case put by Cuvier; the only difference being, that in the Sloth a shell of hard ivory is substituted for the ordinary shell of hard enamel. And so exactly does this shell, to the naked eye, simulate the appearance of enamel, that Cuvier and every other naturalist down to 1837 described it either as being enamel or analogous to it. Enamel is equally absent from the teeth of the whole of the *Megatheroid*

* "Toutes ces choses se déduisent l'une de l'autre selon leur plus ou moins de généralité, et de manière que les unes sont essentielles et exclusivement propres aux animaux à sabot, et que les autres, quoique également nécessaires dans ces animaux, ne leur seront pas exclusives, mais pourront se retrouver dans d'autres animaux, où le reste des conditions permettra encore celles-là." (Cuvier, Discours prélim. p. 50, 4to edit.) Alter the words "animaux à sabot" into "animaux carnivores," and the clause in italics is applicable to the fore-arm of the Sloths. It were easy to show, that the construction of the Sloths, so far from weakening the evidence as to the law of necessary correlation, does, in fact, furnish the strongest arguments in favour of it.

† Owen, *Odontography*, vol. i. p. 330.

Edentata, as from the Sloths. But so little do the united instances furnish a case of means inadequate to the end, that Clift, in 1836, supplied Buckland with a drawing of the teeth of *Megatherium* in opposition, in which the hard shell is figured and described as enamel, and the harder parts of the reversed teeth are shown to be brought in contact with the softer, in such a manner, that mastication is performed and maintained by a series of wedges "like the alternate ridges on the rollers of a crushing-mill," and accompanied by a property, the perfection of all machinery, namely, that of maintaining itself perpetually in perfect order by the act of performing its work*.

Enamel, therefore, although structurally absent, is *functionally* present in the substituted shell of hard ivory. The force of Mr. Huxley's objection is thus narrowed to the use in the Sloth of a material different from the ordinary one. Does this furnish any good argument against the law of correlation? In physics analogous cases of substitution are met with; for instance, in Mitscherlich's isomorphous salts, wherein certain bases may be substituted indifferently, but the combinations will always result in the same function, *i. e.* crystallize in the same geometrical form. No one has on this account doubted the constancy of the laws of crystallization. In predaceous birds, the teeth and jaws of the Carnivora are replaced by the mandibles and hooked bill; but the claw of the Eagle is, notwithstanding, as much in correlation with the bill, as the retractile claw with the scissorial carnassial tooth in the Tiger, the types of construction being different.

Mr. Huxley's next objection is startling. He asks: "Why should not unguulate animals be carrion-feeders? or even, if living animals were their prey, surely a horse could run down and destroy other animals with at least as much ease as a wolf." There are certain Ungulata which do sometimes eat flesh and carrion. The Hog is an example. Cases have been asserted on respectable evidence of its even having eaten young children. But the molar teeth, unlike those of the typical Ungulata, are tubercular or mammillated, not flat, and they differ otherwise. "Among the extinct aberrant forms" (in the *Suide*) "the *Hippolytus* presents almost a ruminant pattern of the grinding surface, while the *Charopotamus* manifests in its whole dentition a close resemblance to the plantigrade Carnivora." "Nothing as yet is known of the incisors of the *Charopotamus*; the rest of the dentition closely resembles that of the Peccari; but the premolars are more simple, and the canines, by their size, shape and direction, and the lower jaw by the backward prolongation of its angle, alike manifest a marked approximation to the

* Buckland, *Bridgewater Treatise*, p. 148.

Ferine type. The occasional carnivorous properties of the common Hog are well known, and they correspond with the minor degree of resemblance which this existing Pachyderm presents to the same type*." On the other hand, "The essential characteristic of the dentition of the true Bears is the development, in the lower jaw, of the true molar teeth to their typical number in the placental Mammalia, and their general manifestation, in both jaws, of a tuberculate grinding surface†." In other words, the Hog and some of its allies, in certain respects, diverge in their structure from the ungulate towards the carnivorous type; while conversely, the Bears similarly diverge from the carnivorous type towards the Ungulata; the result being the same,—that is, regarded in the mass, they become omnivorous. But the exceptions, so far from being inconsistent with the law of correlation, furnish fine illustrations of the manner in which its details are carried out, in contrasted cases of mixed types.

But as regards the pure herbivorous Ungulata—say the Horse—with flat grinding teeth when in full wear, the fitting reply to the first part of Mr. Huxley's query would be—Why should not a pair of millstones serve as well to cut up broad cloth as a pair of scissors? The typical Ungulata have their molars constructed on the grinding principle,—the Carnivora on the scissorial; and both physicists and naturalists know, upon a very wide induction, that the antecedents and consequents in these cases are not reciprocals. As to the second part of the query, the teeth and correlative organs tell us that the speed of the Horse is to enable him to run away from his predaceous and other enemies—not to run down, seize, and destroy other animals. Nature, like a thrifty housewife, has endowed him with organs of locomotion suited to his wants, and not gone beyond them.

The last objection raised by Mr. Huxley is, "What purpose, save support, is subserved by the fore-legs of the Dog and Wolf? how large are their clavicles? how much power have they of rotating the fore-arm?" Every one has seen a dog gnawing a bone. If there is flesh or gristle on it, his paws (*i. e.* the prehensile function of the combined clavicle, scapula, and fore-arm) enable him to place the object in the most favourable position for his jaws to act. If it is flat, like a blade-bone, he can raise it edgewise and so on; being selective acts of manipulation, which are impossible to the Horse with his less artificially endowed fore-arm. All this is familiar and elementary knowledge; the only marvel is, that one should have to adduce the facts at the present day in such an argument.

* Owen, *Odontography*, vol. i. p. 562.

† *Ibid.* p. 501.

Mr. Huxley then brings certain other considerations to bear. Taking the case of a crustacean fossil impression, he shows that the restoration of the extinct form is founded on the invariable concurrence of the peculiar many-ringed body and jointed limbs, with a certain form of the jaws, and certain relations of the muscles, nervous system, and other internal organs, to the exoskeleton. He adds, "For any physiological necessity to the contrary, the creature might have had its mouth, nervous system and internal organs arranged like those of a fish." The general statement is quite correct, but the corollary is a manifest fallacy; for if, in the adduced instance, the creature had had its mouth, nervous system and internal organs arranged like those of a fish, it would have ceased to be a crustacean and have become a fish. Mr. Huxley, with the skeleton of a hawk before him, might as well say that, for any physiological necessity to the contrary, that creature might have its jaws with teeth, and its internal organs arranged, like those of a tiger. Nature has formed living beings upon certain types, which constitute the basis of methodical nomenclature, and the correlation of part to part, and organ to organ, is adjusted in subordination to those types.

The fallacy involved in his next instance is still more obvious: "If we turn to the botanist, and inquire how he restores fossil plants from their fragments, he will say at once, that he knows nothing of physiological necessities and correlations. Give him a fragment of wood, and he will unhesitatingly tell you what kind of a plant it belonged to; but it will be fruitless to ask him what physiological necessity combines *e. g.* peculiarly dotted vessels with fruit in the shape of a cone and naked ovules, for he knows of none. Nevertheless his restorations stand on the same logical basis as those of the zoologist.

"Therefore, whatever Cuvier himself may say, or others may repeat, it seems quite clear that the principle of his restorations was *not* that of the physiological correlation or coadaptation of organs. And if it were necessary to appeal to any authority save facts and reason, our first witness would be Cuvier himself, who in a very remarkable passage two or three pages further on ('Discours,' pp. 184, 185) implicitly surrenders his own principle."

Now, plants have only organic or vegetative life, limited to nutrition and reproduction. But animals, besides this *organic*, have *sensorial* life superadded. Supposing a question were raised as to the reality of sensorial life, what would be thought of the naturalist who would turn to the botanist and say, "Your plants assuredly have not got sensation, perception, and voluntary motion, therefore animals are not likely to have them"? The argument drawn by Mr. Huxley *from* instances

of empirical relation in the vegetable kingdom *against* there being necessary or reciprocal relation in the higher classes of the animal kingdom, if it means anything, is exactly of this character. The truth being, that in both plants and animals there are two kinds of relation between the constituent parts or organs: the one *empirical*, of which we know the invariable constancy, although, so far as our present knowledge goes, we cannot show the reason; the other reciprocal, of which we equally know the constancy, and at the same time can demonstrate the necessity. Physiology takes cognizance of both; and as a general expression of the phænomena it may be stated, *that the necessary relations are more numerous and obviously manifested in the ratio of the higher organization of the living form.* Hence the paramount importance of the principle of reciprocal relation as a guide in mammalian palæontology.

So far as regards the terms above quoted, in which the supposed refutation of the Cuvierian principle is summed up, rarely in the history of science has confident assertion been put forward, in so grave a case, upon a more erroneous and unsubstantial foundation. Later palæontologists are brushed aside with still lighter consideration. They are *les moutons que suivent* "the compilers, and copiers, and popularizers, and *id genus omne.*" It is some consolation to this *pecus ignobile* to reflect, that Professor Owen has been among their number. Mr. Huxley holds him up in the sequel, as furnishing a bright example (of which more anon) of empirical deduction; but it must be admitted, that the Hunterian Professor's numerous works, and reiterated avowals, somewhat compromise him as a rational correlationist*.

Let us now consider what was the method actually followed by Cuvier in the determination and restoration of extinct fossil forms. He first examined, through every organic detail, a vast number of living forms, derived from every class and order of the Vertebrata, with infinite labour and assiduity, during thirty years. In the spirit of pure induction, he ascended from the aggregate of the particular observations to general conclusions; namely, that certain laws of correlation invariably preside over the organization of animals. He found that these laws were classifiable under two heads: 1st, what he called *rational* (i.e. general) laws, wherein the correlation is demonstrable as being necessary and reciprocal throughout the parts, just as the form of a piston must be a reciprocal of the cylinder in which it

* Mr. Owen flies his hawk at a more ambitious quarry in original research; but it is not too much to expect that he may on some occasion record his protest against Mammalian Palæontology being asserted to rest merely on empirical correlation, in a pithy foot-note.

works ; 2nd, *empirical* laws, where the constancy of the correlation is invariable, but the cause is not manifested ; such as that Ruminants alone should have cloven feet and horns on their frontals, concurrently with certain peculiarities in their teeth : thus establishing a harmony—constant, yet wholly inexplicable—between remote organs apparently unconnected ; or, to use the definition of Mr. Huxley, “the invariable coincidence of certain organic peculiarities established by induction.”

Having thus arrived at the general conclusions from observation on living animals, Cuvier, in the spirit of the same inductive philosophy, then applied the inverse process of deduction to the fossil remains : *i.e.* from the ascertained general, he reasoned down to the unknown particular, and thus attained those wonderful results, which have been well characterized by a great living writer as being “among those rare monuments of human genius and labour of which each department of exertion can scarcely ever furnish more than one, eminent therefore above all the efforts made in the same kind*.” Throughout his great work there is that continual alternate use of the *inductive* and *deductive* method, which, Herschel remarks, is essential to the successful process of scientific inquiry. The case of all others to which he most proudly referred, was the determination of the Eocene Opossum of the Paris basin. The crushed skeleton of a minute quadruped was found in a slab of gypsum, and Cuvier employed the following process of analysis for its identification :

1. The teeth, and skeleton throughout, indicated a mammifer.
2. The elevation of the coronoid apophysis above the condyle, and the form of the acute posterior angle of the lower jaw, indicated a predaceous animal.
3. The general construction of the skeleton excluded the *Cheiroptera*.
4. The elevation of the condyle above the horizontal line of the teeth eliminated the ordinary Carnivora, such as Dogs, Cats, Martens, &c. ; but was consistent with placental Insectivora, such as the Mole and Hedgehog, and likewise with Opossums and other marsupials.
5. The molar teeth also were consistent with both placental and implacental Insectivora.
6. The height and width of the coronoid apophysis, and the peculiar inflection of the posterior angle of the lower jaw, eliminated the placental Insectivora, leaving *Didelphys* and other marsupials.
7. Special characters of the teeth excluded all the other marsupials except *Didelphys* and *Dasyurus*.

* Brougham, Dissert. vol. ii. p. 113.

8. The number of the incisors excluded *Dasyurus*, leaving only *Didelphys*.

9. The sum of all the characters throughout the skeleton, and each of them taken separately, indicated *Didelphys*.

10. Therefore the fossil animal was a *Didelphys*, like the non-prehensile tailed Opossums, which are now restricted to the American continent.

If, in turn, we analyse the process, it is obvious that the result was obtained, first by determining the class, and then eliminating, by a series of successive steps, every differential condition, down to a single residual form; and if we examine the nature of the correlations upon which the successive steps were founded, it will be seen that most of them were of the *necessary* order, and but few of the *empirical*. Cuvier was confident, upon the evidence, that the conclusion was sound: but a *crucial instance* remained, by which to verify it. If the extinct form was an Opossum, it must have had a marsupial pouch, and to sustain the pouch, marsupial bones were necessary. He summoned some competent friends to witness the expected verification. A portion of gypsum was cleared away from the slab by the graver, at a sacrifice of some of the vertebræ, and a pair of marsupial bones, concealed in the matrix, were brought to light, resting in their natural position above the edge of the pubis. Thus, after determining the class, the first step in the further analytic deduction rested upon a *rational* or necessary correlation, and so also did the last, crowning the identification. When referring, afterwards, to this signal triumph, the great anatomist quietly remarked: "Je laisse cet article tel qu'il a paru d'abord, dans les annales du Muséum, comme un monument, selon moi assez curieux, de la force des lois zoologiques, et du parti que l'on peut en tirer."

Let us next examine what the true principle is, according to Mr. Huxley. It is not denied, that in palæontology, legitimate consequences may be deduced from the laws of living form: on the contrary, the whole science is admitted to be built on them. But the process of restoration depends, "*not* on the physiological correlation or coadaptation of organs;" but, "first, on the validity of a law of the invariable coincidence of certain organic peculiarities established by induction; secondly, on the accuracy of the logical process of deduction from this law." Now, the ability to demonstrate a proposition, or to infer a legitimate deduction, may be a measure of the capacity of the individual, but it is no criterion of the abstract truth of either. The second clause may therefore be struck out, as self-evident and superfluous. The principle is thus limited to "the invariable coincidence of certain organic peculiarities." This invariable coincidence may

be, as has been shown above, either *empirical* or *necessary*. Cuvier, like a true interpreter of nature, employed both indifferently in his restorations, according as they were presented to him, and professed it. This important fact is *nowhere* recognized by Mr. Huxley, who argues the case throughout as if Cuvier had excluded the empirical and admitted only of necessary correlations. He, on the other hand, denies any share to the latter, and attributes the whole weight to the former. This is also implied by the antithesis between "physiological correlation or coadaptation of organs" (Cuvier), and "invariable coincidence of organic peculiarities" (Huxley). The same is manifested in the references to the sculptured pollen-grains, the forms and colours of flowers, the relation between the dotted vessels and naked ovula in the Gymnosperms, and the crustacean illustration. They are all empirical, so far as science can at present show. The special instance adduced is of the same nature: "Professor Owen's determination of the famous Stonesfield mammal is a striking illustration of this" (*i. e.* of reasoning from the law, by the logical process). "A small jaw of a peculiar shape was found, containing a great number of teeth, some of which were imbedded by double fangs in the jaw. Now these laws have been inductively established—

"(a.) That only Mammals have teeth imbedded in a double socket (*empirical*).

"(b.) That only Marsupials have teeth in so great a number imbedded in so peculiarly formed a jaw (*empirical*).

"By deduction from these laws to the case in question the legitimate conclusion was arrived at, that the jaw belonged to a Marsupial mammal."

Mr. Huxley has been as unhappy in this instance as with the Sloth, for it so happens, that the observed characters do not bear out this asserted deduction. The Stonesfield mammal *par excellence* is the genus *Amphitherium*, which shows the greatest number of teeth (sixteen on either side of the lower jaw), while *it wants* the peculiar marsupial inflection of the posterior angular process, or, at least, does not exhibit it in a greater degree than the placental Mole and Hedgehog. The balance of the evidence therefore "turns the scale in favour of its affinities to the placental Insectivora*." On the other hand, the second Stonesfield genus discovered long afterwards, *Phascolotherium*, has fewer teeth (only twelve on either side of the lower jaw), while *it does* exhibit the marsupial inflection of the angular process. "On reviewing, therefore, the whole of the osteological evidence, it will be seen that we have every reason to presume that the *Amphitherium* and *Phascolotherium* of Stonesfield re-

* Owen, Brit. Foss. Mamm. p. 61.

present both the Placental and Marsupial classes of Mammalia* (*i. e.* the former Placental, the latter Marsupial).

In all the sciences of observation, a great part of our knowledge, at an early stage, is, and must needs be, empirical. It is the same in physics as in natural history. But the constant effort of every philosophical mind is to extinguish the empirical character of the phænomena, and bring them within the range of a rational explanation. Every successful effort of this kind is regarded as so much fertile land reclaimed from the sterile domain of the ocean; and there is an irrepressible revulsion of feeling on seeing the dykes breached for a fresh submergence. In astronomy, Kepler's laws of the planetary motions remained for upwards of a century purely empirical; but at length they were proved to be a necessary consequence of the Newtonian system. Bode's law of the progression of the magnitudes of the planetary orbits still remains empirical. In physiology, animal heat, and the phænomena of sensation and voluntary motion, remained for many ages purely empirical. The most untiring application was devoted to them until the problems were, in a greater or less degree, rationally solved. The name of Charles Bell is imperishably connected with one of these solutions; for mankind has invariably received with a grateful triumph every instance where the demonstration of a great principle has superseded empirical darkness; and such was the feeling with which it recognized Cuvier's announcement and demonstration of the zoological laws of reciprocal relation as furnishing a guide in the reconstruction of extinct vertebrate forms. It is a rare spectacle to see empiricism chosen by preference.

Considering the pre-eminent services of Cuvier and the estimation in which they have hitherto been held, it might have been expected that Professor Huxley, in placing himself in collision with such an antagonist, would have taken every pains to arrive at an accurate appreciation of the position which he combated, and that he would have stated the case impartially; "*modeste tamen et circumspecto judicio de tantis viris pronuntiandum est.*" But we fail to detect the indications of either. The case is only put in part, and the luminous exposition of the great anatomist is met by special pleading, and technical or light objections, beside the real scope of the argument. The result is, that after the encounter the law of correlation stands exactly as Cuvier found and left it,—inscribed by nature in indelible characters on the organization of every living and extinct vertebrate form, and wholly uninjured by its latest assailant.

* Lyell, *Manual*, 5th edit. p. 313.

Throughout Mr. Huxley's *brochure* there runs a strain of extolment of what is empirical in natural history at the expense of the rational. Let him be the great expounder of its aesthetics, if he likes,—every one will cheer him on. But he must beware of attempting to put back the hand of the rational dial, for every arm will be against him. The circulation of the blood has been stoutly denied in Britain within the memory of thousands now living. Strange events of this kind make their appearance periodically in all the sciences. They are anachronisms, which startle by their unexpectedness, and then pass into oblivion. How different were the aspirations of Cuvier! “Avec cette dernière précaution,” (*i. e.* le habitude de ne se rendre qu'à l'évidence, ou du moins de classer les propositions d'après le degré de leur probabilité) “il n'est aucune science que ne puisse devenir presque géométrique: les chimistes l'ont prouvé dans ces derniers temps pour la leur; et j'espère, que l'époque n'est pas éloignée où l'on en dira autant des anatomistes.”

One other remark is necessary. Although the principle of correlation is borne out by a cumulative mass of evidence that is irresistible, it must not, in practice, be pushed too far in paleontology. There are numerous instances on record, in which, in attempting to determine extinct forms from a single bone or tooth, or from imperfect materials, very erroneous conclusions have been arrived at; among others, even by Cuvier himself. And since his time, the same lower jaw, presenting nearly the whole series of teeth, has been referred, by different eminent comparative anatomists, to a fish, a reptile, and a mammal! When these cases are examined under the light of improved knowledge, they furnish no grounds to weaken our confidence in the constancy of the zoological laws of correlation; but an emphatic warning to interpret the evidence carefully, leaving no part of it out, and to eschew hasty conclusions where it is inadequate.

De Blainville, smarting under the sting of some signal misinterpretations committed by himself, unceasingly inveighed against the sufficiency of a single fossil bone for the reconstruction of the form. At the present day, some molar teeth of a fossil mammifer have been met with in the Trias of Stuttgart. The cast of one of them has been shown to one of the most competent living authorities, who, it is stated, “is not able to recognize its affinity with any mammalian type, recent or extinct, known to him.” But when *Microlestes antiquus* is better known, upon more copious materials, we may have every confidence, judging from past experience, that its teeth will be found to be in perfect harmony with the rest of its organization, and amenable to the laws of zoological correlation.