On motion of Mr. Price, the following resolution was adopted:

Resolved, That the Treasurer be authorized to pay to the Treasurer of the Fairmount Park Commissioners, three hundred dollars ($300) of the interest or rent lately received on the Michaux Legacy, to be applied towards the Michaux Grove and Michaux Nursery of Oaks in the Park, agreeably to the resolution of March 18th, 1870 (see page 312, Vol. XI., Proceedings A. P. S.)

And the meeting was then adjourned.

THE METHOD OF CREATION OF ORGANIC FORMS.

By Ed. D. Cope.

(*Read before the American Philosophical Society, December* 15*th*, 1871.)

Chapter I.—On the Law of Acceleration and Retardation. Nature of law of Natural selection. Two kinds of evidence. Illustration. Examples from cervidæ, helicidæ, insects and men.

Chapter II.—The Law of Repetitive Addition. Segment and cell repetition. Illustration from limbs and vertebral column. A, On segment addition; definitions. On repetition in bilateral and anteroposterior symmetry; in structure of compound teeth; in segments of articulata; limbs of Reptilia; brain of lamprey. B, On cell repetition; simple segment a repetition of cells; simple diverticulum the same. The cell theory; the nucleated cell. C, Synthesis of repetition. From unicellular to multicellular animals; simple repetition to compound repetition; *Actinia, Lepidosiren, Ichthyosaurus, Plesiosaurus, Tœnia;* the heart; mammalian teeth. D, On growth force; relation to other forces; definition. E, Direction of repetition, its location, centrifugal and longitudinal; movements longitudinal. Inheritance; its relation to growth force.

Chapter III.—The Law of Use and Effort. Points to be investigated. A, On the location of growth force. Relation of effort to use. Rudimental characters. Examples of growth under influence of physical laws; Examples of colors under influence of light. Use and disuse of gills. Rattlesnake; horned animals. Teeth of ruminants. B, Change in amount of growth force. Local increase of growth force. Convoluted structures; brain, teeth, cotyledons. Absolute loss of growth force. Teeth and toes of Ruminants; incisors of Rodents.

Chapter IV.—On Grade Influence. A, On the nature of Grade influence or Bathmism. Definitions. In plants; in animals. Increase in time of Bathmism and growth force. Vital forces and vital influences. Thought force. Origin of Bathmism in time. B, Physiological origin of Bathmism. Function of nervous system in force conversion. Automatic and habitual movements. Effect on nervous system. C, The transmission of grade influence. Secretion in general. Spermatozoöids.

Chapter V.—Intelligent Selection. Development of intelligence. Stimuli to use. Compulsion, Choice; Bees, Food, Rattlesnake; Change of color; Mimetic analogy, Examples. Development of character.

In the present state of biological science, essays like the present can only be tentative in so far as they treat of the laws of evolution. Nevertheless the present time is preëminently one of generalization in this field, and properly so. Facts have been accumulating for a long period, and are now sufficiently numerous to yield important results, under proper classification and induction. Darwin led the way in this work, and the development hypothesis is regarded as demonstrated by most biologists. The discussion of the laws of its progress involves a multitude of subordinate hypotheses. In the following essay, these are arranged under five prominent heads, viz: 1, The law of Acceleration and Retardation; 2. The law of Repetitive Addition; 3. The law of Use and Effort; 4. The law of Grade Influence; 5. The law of Intelligent Selection. Of these, the first and second are regarded by the author as demonstrated, the third and fourth as only reduced to a partial demonstration, while the fifth is a consequence of the third, and stands or falls with it.

The discussion of this subject divides itself into two parts, viz: a consideration of the proof that evolution of organic types or descent with modification has taken place; and secondly, the investigation of the laws in accordance with which this development has progressed. As the latter involves the use of the evidence included in the former, I will not devote a special chapter to the proof for evolution.

The influences and forces which have operated to produce the type structures of the animal kingdom have been plainly of two kinds; 1. *Originative*, 2. *Directive*. The prime importance of the former is obvious; that the latter is only secondary in the order of time or succession, is evident from the fact that it controls the preservation or destruction of the results or creations of the first, and thus furnishes the bases of the exhibitions of the originative forces in the production of the successive generations of living beings.

Wallace and Darwin have propounded as the cause of modification in descent their law of natural selection. This law has been epitomized by Spencer as the "survival of the fittest." This neat expression no doubt covers the case, but it leaves the origin of the fittest entirely untouched. Darwin assumes a "tendency to variation" in nature, and it is plainly necessary to do this, in order that materials for the exercise of a selection should exist. Darwin and Wallace's law is, then, only restrictive, directive, conservative, or destructive of something already created. I propose then to seek for the originative laws by which these subjects are furnished—in other words, for the causes of the origin of the fittest.

It has seemed to the author so clear from the first as to require no demonstration, that Natural Selection includes no *actively* progressive principle whatever; that it must first wait for the development of variation, and then after securing the survival of the best, wait again for the best to project its own variations for selection. In the question as to whether the latter are any better or worse than the characters of the parent, natural selection in no wise concerns itself.

I. ON THE LAW OF ACCELERATION AND RETARDATION.

There are two modes of demonstration of evolution, both depending on direct observation. One of these has been successfully presented by Darwin. He has observed the origin of varieties in animals and plants, either in the domesticated or wild states, and has shown, what had been known to many, the lack of distinction in the grades of difference which separate varieties and species. But he has also pointed out that species (such, so far, as distinctness goes) have been derived from other species among domesticated animals, and he infers by induction that other species, whose origin has not been observed, have also descended from common parents. So far, I believe his induction to be justified; but when from this basis evolution of divisions defined by important structural characters, as genera, orders, classes, etc., is inferred, I believe that we do not know enough of the uniformity of nature's processes in the premises to enable us to regard this kind of proof as conclusive.

I therefore appeal to another mode of proving it, and one which covers the case of all the more really structural features of animals and plants.

It is well known that in both kingdoms, in a general way, the young stages of the more perfect types are represented or imitated with more or less exactitude by the adults of inferior ones. But a true identity of these adults with the various stages of the higher has, comparatively, rarely been observed. Let such a case be supposed.

In *A** we have four species whose growth attains a given point, a certain number of stages having been passed prior to its termination or maturity. In *B* we have another series of four (the number a matter of no importance), which, during the period of growth, cannot be distinguished by any common, *i. e.*, generic character, from the individuals of group *A*, but whose growth has only attained to a point short of that reached by those of group *A* at maturity. Here we have a parallelism, but no true evidence of descent. But if we now find a set of individuals belonging to one species, or still better, the individuals of a single brood, and therefore held to have had a common origin or parentage, which present differences among themselves of the character in question, we have gained a point. We know in this case that the individuals, *a*, have attained to the completeness of character presented by group *A*, while others, *b*, of the same parentage have only attained to the structure of those of group *B*. It is perfectly obvious that the individuals of the first part of the family have grown further, and, therefore, in one sense faster, than those of group *b*. If the parents were like the individuals of the more completely grown, then the offspring which did not attain that completeness may be said to have been *retarded* in their development. If, on the other hand, the parents were like those less fully grown, then the offspring which have added something, have been *accelerated* in their development.

I claim that a consideration of the uniformity of nature's processes, or inductive reasoning, requires me (however it may affect the minds of others) to believe that the groups of species, whose individuals I have

*A cut explaining this proportion will be found at the end of the essay.

never found to vary, but which differ in the same point as those in which I have observed the above variations, are also derived from common parents, and the more advanced have been *accelerated* or the less advanced *retarded*, as the case may have been with regard to the parents.

This is not an imaginary case, but a true representation of many which have come under observation. The developmental resemblances mentioned are universal in the animal, and probably in the vegetable kingdoms, approaching the exactitude above depicted in proportion to the near structural similarity of the species considered.

Example 1. It is well known that the *Cervidæ* of the Old World develop a basal snag of the antler, (see Cuvier, Ossemens Fossiles, and Gray, Cat. British Museum,) at the third year; a majority of those of the New World (genera Subulo, Cariacus) never develop it except in abnormal cases in the most vigorous maturity of the most northern Cariacus (*C. virginianus*), while the South American Subulo retains to adult age the simple horn or spike of the second year of all *Cervidæ*.

Among the higher *Cervidæ*, Rusa and Axis never assume characters beyond an equivalent of the fourth year of Cervus. In Dama the characters are, on the other hand, assumed more rapidly than in Cervus, its third year corresponding to the fourth of the latter, and the development in after years of a broad plate of bone, with points being substituted for the addition of the corresponding snags, thus commencing another series which terminates in the great fossil elk, Megacerus.

Returning to the American deer we have Blastocerus, whose antlers are identical with the fourth year of Cariacus. Corresponding with the Dama-Megacerus type of the Old World we have the moose (Alces) developing the same palmate horn on the basis of Cariacus (*i. e.*, without eye-snag.)

Example 2.—I select the following series, embracing the majority of the genera of the North American Helicidæ.*

1. Turns of spire very few; wide umbilicus; shell thin, with thin lips...*Binneya.*
2. Turns few, but more; rest as above..........................*Vitrina.*
3. Turns still more numerous; rest as above................*Hyalina.*
4. As No. 3, but lip thickened inside.......................*Hygromia.*
5. Coiled; *umbilicus closed;* lip thickened inside and out, *Tachea* and *Pomatia.*
6. Same, with a parietal tooth..............................*Mesodon.*
7. Same, with parietal and two interior lip teeth.......*Isognomostoma.*

* * Recommencing at No. 4. All with *open umbilicus.*

5. As No. 4, but lip thickened in and out....................*Arionta.*
6. Same as No. 5, but with parietal tooth..................*Polymita.*
7. Same, with both parietal and lip teeth..................*Triodopsis.*

* See Tryon, Terrestrial Mollusca of the United States. Probably other (*e. g.* dental) characters distinguish some of these genera, but the above furnishes the history of one set of characters.

The successional relation of these genera may be represented in such a diagram as this:

	Umbilicus open.						Umbilicus closed.
7	*						*
6		*				*	
5			*		*		
4				*			
3				*			
2				*			
1				*			

In the history of the growth of the genera Isognomostoma and Triodopsis, the extreme forms of the two series, it is well known that at first the coils of the shell are extremely few, as in Binneya; and that like it, it is very thin and with a delicately thin edge; that the turns increase successively in number, as in Vitrina and Hyalina, and that finally the lip thickens as in Hygromia. Then the umbilicus may close as in Tachea, or (in Triodopsis) remain open as in Arionta. In either case a tooth is soon added on the body whorl (Polymita, Mesodon), and finally, the full maturity of the shell is seen in the added teeth of the inside of the lip margin. How many of the stages of the genera *Triodopsis* and *Mesodon* are identical with the genera of the series which represent them, I leave to more thorough conchologists, but that some now exhibit and all have once presented illustrations of the relation of exact parallelism, I cannot doubt.

Example 1.—An abundant race of the American deer, *Cariacus virginianus*, exists in the Adirondack region of New York, in which the development of the antlers never progresses beyond the spike stage of the second year. Therefore, some individuals of this species belong to Cariacus and some to Subulo.

Example 2.—A large part of the individuals of the common snail, *Mesodon albolabris*, never develop the tooth of the body-whorl, characteristic of the genus whose definition has to be modified to retain them.

Example 3.—Many individuals of *Triodopsis tridentata* from eastern North Carolina occur without the lip-teeth, characteristic of the genus *Triodopsis*. Hence these specimens, though of common origin with others of the species, must be referred to another genus.

Example 4.—Structural characters are known in many, if not all, species which are said to be "inconstant," being present or absent indifferently, thus being useless for definition. They may be rudimental when present or considerably developed. The presence or absence of wings in some species of insects may be cited; also the presence of generic characters in the male sex of many Coleoptera and their absence in the females. The characters of males, females, workers and soldiers in bees and ants may be added. All these facts belong to the same category as those cited among deer and mollusks and have a similar explanation.

Example 5.—It does not seem to be the law in "retardation" that parallelisms exhibited by the series in its rise to its highest point of development should retrace the steps by which it attained it, and that "exact parallelisms" should be exhibited in a reversed order. Parallelisms, it is true, are exhibited; but so far as I have observed always "inexact," often in a high degree. A marked case of retardation occurs in the dental development of a number of persons who have come under my observation in the neighborhood of Philadelphia. It is not very uncommon to find persons in whom the third molars in both jaws are incomplete as to number, one, two, three, or all, being deficient. It is still more common for them to be incompletely covered by the enamel layer, and to become in consequence so worthless as to require early removal. I am acquainted with two families in which the absence of the exterior upper incisor on each side is common. In one of these the second and third generation have inherited it from the mother's side, and it now characterizes many of the children. The significance of this modification will be best understood by examining the dental structures of the *Quadrumana* in general. Commencing with the highest family and its abnormal dentition, we have:—

	Incisors.	Canines.	Premolars.	Molars.
Hominidæ, .. Abnormal.	$\frac{1}{2}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{2}{3}-\frac{2}{2}$
Hominidæ, .. Normal.	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{3}{3}$
Simiidæ..................	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{3}{3}$
Cebidæ..................	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{3}{3}$	$\frac{3}{3}$
Lemuridæ	$\frac{2}{3}$	$\frac{1}{1}$	$\frac{3}{3}-\frac{2}{3}$	$\frac{3}{3}$
Mammalia, Normal......	$\frac{3}{3}$	$\frac{1}{1}$	$\frac{4}{4}$	$\frac{3}{3}$

In this table we see a decline in the number of teeth of the higher groups. Thus, the premolars are one less than the normal number in the whole order, and they lose one in each jaw in the Old World apes, and man. The molars maintain the normal number throughout, but the third in both jaws is in the *Simiidæ* reduced by the loss of a fifth or odd tubercle, thus becoming four-lobed. In the upper jaw, this is first lost in the Semnopithecus; in the lower, in the next highest genus Cercopithecus. In Homo its appearance is "retarded," the interval between that event and the protrusion of the second molar—six to ten years—being relatively greater than in any genus of *Quadrumana*. Its absence is then the result of continued retardation, not of a new and adaptive suppression, and is of direct systematic zoological value.

In the incisors a reduction is also plainly visible, as we pass from the most completely furnished mammals to the genus Homo. One from the upper jaw is first lost, then in the *Cebidæ*, one from the lower also. The number remains the same through the *Simiidæ* and normal *Hominidæ*, but in the abnormal cases cited, the process of reduction is continued and another incisor from each side disappears. That this also is truly "retardation" is also evident from the fact, that the exterior incisor is the last developed, being delayed in ordinary growth a year later than those of the inner pair. The same retardation is seen in the quadrumane *Cheiromys* (the *Aye-aye*), and the whole order *Rodentia*. In the latter, the rare presence of the reduced second incisors, as in *Lepus*, shows a less degree of this modification. This retardation is also of systematic importance, and, should either of the characters described be constant in any of the species of the genus *Homo*, would at once entitle it to new generic rank. The very frequent absence of the posterior molars (wisdom teeth) has been recently found to characterize a race in India. Should this peculiarity prove constant, this race would with propriety be referred to as a new genus of *Hominidæ*, as we have many cases of very similar species being referred to different genera. It is altogether probable that such will, at some future time be the condition of some race or races of men.*

I am now disposed to regard the above as the method of production, not only of generic but of all other, including specific characters. It would appear that by excessive acceleration or retardation, some of the characters of a series may be skipped, but observations are not conclusive on this point, since very close examination is necessary for the appreciation of very transitory embryonic conditions.

II. ON THE LAW OF REPETITIVE ADDITION.

The origin of new structures which distinguish one generation from those which have preceded it, I have stated to take place under the law of *acceleration*. As growth (creation) of parts usually ceases with maturity, it is entirely plain that the process of acceleration is limited to the period of infancy and youth in all animals. It is also plain that the question of growth is one of nutrition, or of the construction of organs and tissues out of protoplasm.

The construction of the animal types may be referred to two kinds of increase—the addition of identical segments and the addition of identical cells. The first is probably to be referred to the last, but the laws which give rise to it cannot now be explained. Certain it is that segmentation is not only produced by addition of identical parts, but also by subdivision of a homogeneous part. In reducing the vertebrate or most complex animal to its simplest expression, we find that all its specialized parts are but modifications of the segment, either simply or as sub-segments of compound but identical segments. Gegenbaur has pointed out that the most complex limb with hand or foot, is construc ted, first, of a single longitudinal series of identical segments, from each of which a similar segment diverges, the whole forming parallel series, not only in the oblique transverse, but generally in the longitudinal sense. Thus, the limb of the Lepidosiren represents the simple type, that of the Ichthyosaurus a modification. In the latter, the first segment only (femur or humerus) is specialized, the other pieces being undistinguishable. In the Plesiosaurian paddle the separate parts are distinguished; the ulna and radius well marked, the carpal pieces hexagonal, the phalanges defined, etc.

As regards the whole skeleton the same position may be safely assumed. Though Huxley may reject Owen's theory of the vetebrate char-

*The preceding section is merely an abbreviation with new illustrations, of the propositions brought forward in the writers "Origin of Genera," 1868, where a considerable extension of the subject will be found.

acter of the segments of the brain case, because they are so very different from the segments in other parts of the column, the question rests entirely on the definition of a vertebra. If a vertebra be a segment of the skeleton, of course the brain case is composed of vertebræ; if not, then the cranium may be said to be formed of "sclerotomes," or some other name may be used. Certain it is, however, that the parts of the segments of the cranium may be now more or less completely parallelised or homologised with each other, and that as we descend the scale of vertebrated animals, the resemblance of these segments to vertebræ increases, and the constituent segments of each become more similar. In the types Amphioxus, etc., where the greatest resemblance is seen, segmentation of either is incomplete, for they retain the original cartilaginous basis. Other animals which present cavities or parts of a solid support are still more easily reduced to a simple basis of segments, arranged either longitudinally (worm) or centrifugally (star-fish, etc.)

DEFINITIONS.

α The succession of construction of parts of a complex, was originally a succession of identical repetitions; and grade influence merely determined the number and location of such repetitions.

β *Acceleration* signifies addition to the number of those repetitions during the period preceding maturity, as compared with the preceding generation, and *retardation* signifies a reduction of the numbers of such repetitions during the same time.

γ The successive additions now characterizing the growth of the highest animals are not exact repetitions of segments at this time, because of influences brought to bear on cell nutrition during long periods. The nature of these influences is made the subject of another section.

In the endeavor to prove these positions, I will produce evidence, first, that some simpler animals grow according to the principle of modified repetitive addition, and that traces of it are to be observed in the most complex ; second, that every addition to structure which has resulted in the complexity of the higher animals, was originally a repetition of a preexistent structure.

Detailed explanations of the law of repetitive addition are attempted in the following pages, under two heads, segment repetition, and cell repetition.

A. On Segment Repetition.

This is everywhere seen in the construction of animals and plants Double bilateral symmetry may serve as one example of repetition in growth.

a Bilateral symmetry. Anatomists have little difficulty in determining the bilateral symmetry in most animals; that is, the homologies of the parts on opposite sides of the median line. It might be almost asserted that it was a necessity of organization, but when we observe the growth of many plants, we are undeceived. And though bilateral symmetry in the *Cœlenterata* and many *Articulata* is perfect, yet in higher animals it is more or less departed from. In the Vertebrata the *Amphioxus* is almost completely bilaterally symmetrical. In the fishes, the digestive system is the only one which does not conform to it; while in the birds the reproductive system is atrophied on one side. In the serpents the respiratory and part of the circulatory are similarly modified; and in the mammalia the digestive and circulatory systems have both become unsymmetrical; and the cranium even in the cetacea.

If evolution be true, the unsymmetrical forms have descended from the symmetrical, and the asymmetry being thus not inherited, is the result of laws which have interfered with the original tendency to bilateral repetition.

Many cases of bilaterally symmetrical diseases have been enumerated by physiologists, and I will select as an example one which has come under my observation. They were those of two boys who had had that disease involving the mucodermal system called Varicella, while the crowns of the successional incisor teeth were still enclosed in the mucous capsules of the alveolar walls. The deposit of phosphate of lime forming their surfaces was interrupted by the disease of the tissue, and the result was a surface pitted, or sculptured intaglio fashion. The sculpture of the two incisors of the right side was precisely imitated by those of the left in reversed order, even in minute details, which were numerous, thus producing a result not displeasing to the eye. This has been observed on two distinct occasions some years apart.

Another interesting example of bilaterally symmetrical disease, is recorded in a paper on "a case of universal hyperostosis, etc.," by Drs. Mears, Keen, Allen and Pepper. * They describe the skeleton of a boy of fourteen which displayed an extraordinarily exostosed condition, the bones themselves remaining in the condition known as osteoporosis. They describe the uniform repetition of the abnormal growths of one side on the other in the following language, (p. 22).

"Comparing the two sides externally, not only is there no difference in the extent and character of the disease, but there is the most remarkable symmetry of the corresponding diseased bones, which may be traced even into details. The disease begins and ends on both sides at corresponding points, it changes in character from simple porosity to the growth of osteophytes at corresponding points; if, on one side, the posterior part of the bone is most diseased, the same is true of the other side; if the osteophyte growth is continuous or interrupted on one bone (fibula fig. 18), it is so on the opposite one; if one is unusually diseased at a tendinous or aponeurotic insertion, so is its mate; if a groove or a variation in color exist on the one side, the same will be found on the other side; even of single marked spiculæ of bone the same may be said, so that a description of one side will answer for both, minute differences being noted as they occur."

b. Antero-posterior symmetry.

That this is an absolute law of creation will be less readily admitted

* See Proceed. Amer. Philos. Soc. 1870, p. 19.

than in the case of double bilateral symmetry, since the exceptions appear to be so universal. Nevertheless, I believe it to be as much a part of the law of Repetitive nutrition as the other. The antero-posterior homologies even of the human skeleton have been largely demonstrated, but as usual, we must appeal to the lower forms for a clear view of it. In the rudimental skeletal axis we find such symmetry almost perfect in the *Amphioxus*, but in no other vertebrate. In limbs we have it clearly indicated in the Reptilian order *Ichthyopterygia*, and in the Piscine order *Dipnoi*, where the anterior and posterior are scarcely or not all distinguishable. In the scapular and pelvic arches we find it also approximated in the first-named orders.

In the nervous system it also exists approximately in the *Amphioxus*. It is not seen in any vertebrate, and in but few other animals, in the digestive system, but it appears to exist in some lower articulata in both the respiratory and circulatory systems.

c. As illustrations of exact repetition involving large portions of the organism the higher Polyps may be cited, which differ from the lower chiefly by the addition of similar septa and similar tentacles. Examples of repetition of nearly the whole organism, may be found in many Entozoa as *Taenia*, where the cephalic segment only differs from the others, the remainder or proglottides being alike. The most entire repetition of structure is seen in *Vibrio*, where the segments are all alike, there being none representing a head.

d. As an example in special details of structure, the segments of the lowest brain (that of the lamprey) are repetitions of the first one. The pelvic arch of *Ichthyosaurus* when first created, was a repetition of the scapular, and the hind limb, of the fore limb. The segments of the limbs of the *Dipnoi* are mere repetitions, the later created of the earlier. The special parts of the pes and manus of *Ichthyosaurus* are simply repetitive efforts of growth-force joined with a diminishing amount. The addition of a digit often distinguishing one genus of Salamanders or Saurians from another, is evidence of a similar repetitive effort. The low mammal *Ornithorhynchus*, possesses but a single tooth in each jaw; the simple teeth of armadillos and cetaceans, increasing as they have done from a single commencement as in the monotreme cited, present examples of repetitive acceleration of growth force.

e. Complication of a single element of repetition is accomplished apparently by a double repetition. This is best understood by the consideration of the transition from simple to complex teeth. In the cetaceans this occurs in the Squalodonts; the cylindric incisors are followed by flattened ones, then by others grooved on the fang, and then by two rooted, but never double-crowned teeth. This is the result of antero-posterior repetitive acceleration of the simple cylindric dental type of the ordinary toothed cetacean.

Another mode of dental complication is by lateral repetition. Thus, the heel of the sectorial tooth of a Carnivore is supported by a fang alongside of the usual posterior support of a premolar, and is the result of a repetitive effort of growth force in a transverse direction. More complex teeth, as the tubercular molars, merely exhibit an additional lateral repetition, and sometimes additional longitudinal ones. As is well known, the four tubercles of the human molar commence as similar separate knobs on the dental papilla.

The above are cited as examples to explain the meaning of the proposition. When fuller demonstration is desired a greater number might be given.

B. On Cell Repetition.

That each additional act of creation in growth was originally identical with one which preceded it, and therefore an *exact repetition* in its character and results, is proven by the following considerations.

It has been already determined by the study of homologies that all organs and parts of an organism can be referred to an original simple archetype.

The question then remains as to whether the first element or lowest term, of a given organized part is essentially a new structure, or whether it be a repetition of some previously existing one. It may be asserted that the simplest expressions which shall cover all organs, are the solid segments and the hollow sack and tube. For example, we have already noted that the ultimate element of the limb is the first segment of the single ray of Lepidosiren. Is this short cartilaginous cylinder (which probably represents the fore-limb of some undiscovered member of the Dipnoi), a result of the repetition of a pre-existent structural element? This is no doubt the case, for as will be shown beyond, cartilage, though the least cellular of all the tissues is formed originally by cell-repetition or division. Again, the ultimate lobules of the most complex gland are but repetitions of the diverticula of the simply branched, and each of the latter repetitions of the simple cul-de-sac, which has its origin in a convexity of an originally plane surface. This convexity is again the result of repetition of cells or cell-division, whereby their number is increased and the surface rendered convex.

We are thus in both the solid segment, and hollow sack, brought down to cell repetition. Thus it is with organs, as with entire animals, in which, following the line of simplification, we reach at last forms composed of cells only, (*Actinophrys, e. g.*) and then the unicellular, (*Amœba*).

If this be the origin of organs, the question whether repetitive growth has constructed tissues, remains for consideration.

In growth, each segment—and this term includes the parts of a complex whole or parts always undivided, (as the jaw of a whale or the sac-body of a mollusk)—is constructed, as is well known, by cell division. In the growing fœtus the first cell divides its nucleus and then its whole outline, and this process repeated millions of times produces, according to the cell theory, all the tissues of the animal organism or their bases, from first to last. That the ultimate or histological elements of all organs are produced originally by repetitive growth of simple nucleated cells, with various modifications of exactitude of repetition in the more complex, is taught by the cell theory. The formation of some of the tissues is as follows:

First Change—Formation of simple nucleated cells from homogeneous protoplasm or the cytoblastema.

Second—Formation of new cells by division of nucleus and body of the old.

Third—Formation of tissues by multiplication of cells with or without addition of intercellular cytoblastema.

A. In connective tissue, by slight alteration of cells and addition of cytoblastema.

B. In blood, by addition of fluid cytoblastema (fibrin) to free cells (lymph corpuscles), which in higher animals (vertebrates) develop into blood-corpuscles by loss of membrane, and by cell development of nucleus.

C. In muscles, by simple confluence of cells end to end, and mingling of contents (Kölliker).

D. Of cartilage, by formation of cells in cytoblast which break up, their contents being added to cytoblast; this occuring several times, the result being an extensive cytoblast with few and small cells (Vogt). The process is here an attempt at development with only partial success, the result being a tissue of small vitality.

Even in repair-nutrition recourse is had to the nucleated cell. For Cohnheim first showed that if the cornea of a frog's eye be scarified, repair is immediately set on foot by the transportation thither of white or lymph or nucleated corpuscles from the neighboring lymph heart. This he ascertained by introducing aniline dye into the latter. Repeated experiments have shown that this is the history in great part of the construction of new tissue in the adult man.

Now, it is well known that the circulating fluid of the fœtus contains for a period only these nucleated cells as corpuscles, and that the lower vertebrates have a greater proportion of these corpuscles than the higher, whence probably the greater facility for repair or reconstruction of lost limbs or parts enjoyed by them. The invertebrates possess only nucleated blood corpuscles.

C. Synthesis of Repetition.

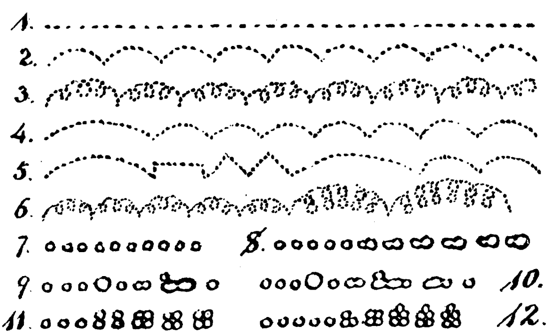
That growth force is capable of exhibiting great complexity of movement with increase in amount, will now be shown. That this quality of complication is one of its distinguishing features will appear plain.

The simplest forms of life, as stated by Hæckel, are simply homogeneous drops of protoplasm (*Protamoeba*). These only grow by ordinary accretion, and display a form of self division or reproduction which is the simplest possible; *i. e.*, the bisection of the mass by contraction at opposite points.

The next grade of animal type is represented by the nucleated cell. This is simple in *Amœba*, complex in *Actinophrys*, etc. With such forms as the latter, cell growth begins, and its development is accomplished by cell division. This is simple repetition of ultimate parts. In the growth of all higher types, we have nothing more than this, but following a law of *complex repetition*. Thus in the growth of the parts of an archetypal vertebral column, or an archetypal limb, we have the repetition of cell growth till the first segment is formed, when it ceases at that point, and repeats the process again, forming another segment like the first; repetition within repetition. So with the construction of muscular tissue; first, the nucleated cell repeated in a series, whose adjacent walls disappear, and whose cell contents flow together, thus forming a fibrilla; then a repetition of the same process forming a second fibrilla; and so on to the completion of thousands of them in fasciculi.

Let us then trace the series of repetitions and duplicated and still more complex repetitions, seen in following up animal forms from their archetypes.

In the simplest repetition of cell growth in a longitudinal direction we have *Vibrio;* in the centrifugal, *Actinophrys*. The former may be represented by a line of simple dots, thus :—Fig. 1.



In a complex repetition we rarely have the same degree of complication in each repeated part. We have it centrifugally almost perfect in a Cœlenterate (*Actinia*) and linearly in some of the lower Entozoa. An archetype of the latter kind might be represented thus :—Fig. 2. In a more complex form, as of the proglottides of *Tænia*, thus :—Fig. 3. The same might represent an archetypal vertebrate.

If now we attempt to express the complication of an organ by modified repetition of once identical parts, the history of extremities will serve us. Thus the limb of Lepidosiren which is composed of identical segments may be thus represented :—Fig. 2. Each longitudinal segment of the limb of Ichthyosaurus may be similarly represented with a modification, in size only, of the proximal or humerus; thus :—Fig. 4. But in *Plesio-*

saurus, an important series of changes of shape (but not in complexity) appears, which may be represented thus :—Fig. 5 ; the first being humerus, second ulna, third and fourth carpals (tarsals) the last phalanges, which are first specialized in this genus.

By far the most usual modification is however complication by duplicated and triplicated and still more highly multiplied repetition in some segments of the archetype, and its omission in other segments. Thus in in the *Tænia*, the cephalic segments are much modified, and the nature of its repetitions might be thus expressed :—Fig. 6 ; the simpler segments representing the body segment, the two complex, representing these of the head. In each, it will be observed, the complication is represented by loops of similar form, and each loop of dots which represent the cells in the first linear (fig. 1) arrangement.

A somewhat similar figure might represent the nature of the complication in the Myriapod. In the insect the additional complications of the thoracic segments would alter the diagram near the middle.

In the vertebrate cranium, a somewhat similar diagram might be used, except that the modification of the segments or vertebræ, as compared with the segments of the vertebral column, is not by repetition with modification of the parts of each segment, but rather by modification of the forms of the parts of the segments. The basi-cranial segments thus compare with the dorsal vertebræ as the segments of the limb of *Plesiosaurus* do to those of *Ichthyosaurus*.

The above considerations have reference to repetition of parts in a linear direction. Centrifugal repetition is seen in the addition of chambers to the heart, by the subdivision in the earliest stages into auricle and ventricle in the linear direction, considered in connection with the earlier division of each in the transverse direction, by the growth of partitions. This mode of repetitive addition is not readily represented by diagram.

A good example of repetitive addition in both linear and transverse direction, may be found in the successive complication of tooth structure seen in mammalia. In the dolphin, the dental series may be represented thus:—Fig. 7; in the squalodon thus:—Fig. 8; in the cat:—Fig. 9; in the dog:—Fig. 10 ; in man :—Fig. 11 ; in some insectivora :—Fig. 12.

The circles represented here, are each a simple cusp.

In conclusion, the directions of Repetitive growth may be tabulated as follows : The types to the left represent the original ; to the right, the derivative.

- Centrifugal.
  - Longitudin'l antero-posterior and bilateral.
    - More bilaterally symmetrical.
      - Only bilateral.
    - More antero-posteriorly.
      - Only antero-posterior.
  - Centrifugal.
    - In plane.
    - In globe.

D. On Growth Force.

From such examples as those that precede, but more especially from the last, it seems necessary to believe that there resides in organized matter, and in its most unmodified representative, the nucleated cell, an affection which displays itself in repetition. This phenomenon reduced to its lowest terms, may mean cell-division only, but the proof is only clear in cases of growth proper. This affection displays itself in very slow or more rapid repetitions,—cell-division in growth occurring rapidly, while its recurrences at rutting seasons in the development of horns, feathers, etc., are separated by long intervals of time. In acceleration these repetitions occur with increased rapidity, *i.e.*, in the adding of more structures during the same growth periods, while in low types its repetitions are few and therefore slow.

What is the relation of cell division to the forces of nature, and to which of them as a cause is it to be referred, if to any? The animal organism transfers solar heat and the chemism of the food (protoplasm) to correlated amounts of heat, motion, electricity, light (phosphorescence), and nerve force. But cell-division is an affection of protoplasm distinct from any of these; although addition to homogeneous lumps or parts of protoplasm (as in that lowest animal, *Protamœba* of Hæckel,) should prove to be an exhibition of mere molecular force, or attraction, cell-division is certainly something distinct. It looks like an exhibition of another force, which may be called *growth force*. It is correlated to the other forces, for its exhibitions cease unless the protoplasm exhibiting it be fed.

Professor Henry pointed out many years ago that this must be the case, basing his belief on the observed phenomena of growth in the potato, and in the egg. The starch of the potato weighs much more than the young shoot of cellulose, etc., into which it has been converted by growth activity, so that a portion of the substance of the tuber has evidently escaped in some other direction. This is shown to be carbonic acid gas and water, derived from the slow combustion of the starch, which in thus running down from the complex organic state, to the more simple inorganic compounds, evolves an amount of force precisely equal in amount to the chemical force (or chemism) requisite to bind together the elements in the more complex substance.*

Carpenter also states that in his opinion the growth of the Fungi is produced by a force liberated by the retrograde metamorphosis of their food, which is of an organic character, (*i. e.*, humus). This metamorphosis consists, as in the tuber, in the production of carbonic acid gas and water, and a force equivalent to the chemism which had bound them in the former complex union.† But in higher forms of vegetable life and in growth that follows germination, the plant must appropriate carbon from the carbonic acid of the atmosphere. The decomposition of the

* Agricultural Report of the Patent Office, 1857.

† Correlation of Physical and Vital Forces, 1864, (Quarterly Journal of Science.)

binary compound (which sets free its oxygen) liberates the chemical force which had previously maintained the compound, (or an equivalent force) which Henry regards as furnishing the growth force, which produces the plant. Carpenter derives but a portion of the force in this way, obtaining the greater part from the heat of the sun. To this source also he looks for the *growth force* employed in the construction of cold-blooded animals; while in warm-blooded animals, the retrograde metamorphosis or running down of the material (protoplasm) of the food, furnishes a requisite amount of heat. Whether growth force be derived from the chemism set free, direct, or through the mediation of heat, by conversion, among higher animals, is a question yet unsolved.

Growth force we may then regard as potential in organized tissue, and as energetic during growth. Our present knowledge only permits us to believe that other force is only converted into it under the influence of pre-existent life, but of the real cause of this conversion we are as ignorant as in the case of the physical forces.

In the animal organism, different tissues display different degrees of "vitality." The most vital display cell-organization and its derivative forms, while the least so, approach nearer to homogeneity. As organized tissue is the machine for converting vital forces, we may believe that less growth force is potential in cartilage than in muscle, for it is formed by a retrograde process, by which cells once formed are mostly burst, and the contents form the intercellular, nearly structureless mass characteristic of this tissue. Growth force must be here liberated in some other form, perhaps heat, to be again converted to other use.

The higher vitality we may believe to result from the greater perfection of the more complex *machine* as a force converter, as compared with the inefficiency of the more simple.

E. On the Direction of Repetition.

It has been already pointed out that *growth force* exhibits itself in cell or segment repetition. The forms in which it thus displays itself may be briefly considered. The approximate cause is treated of in the next chapter; but enough may be shown here to indicate that duplication and complex duplication is the law of growth force, and that therefore this process must always follow *an increase in amount* in any given locality.

The size of a part is then dependent on the amount of cell-division or growth force, which has given it origin, and the number and shape of segments is due to the same cause. The whole question, then, of the creation of animal and vegetable types is reduced to one of the *amount and location of growth force.*

Repetition is of two kinds, *centrifugal* and *longitudinal.* As an example of the former, the genus *Actinophys* has been cited, where the animal is composed of cells arranged equidistally around a common centre. The arrangement in this type may be discoidal or globular, providing no definite axis be discoverable. As an example of *longitudinal* repetition, *Vibrio,* and numerous cellular plants may be cited where the arrangement is in a single line.

In by far the greater number of animals these kinds of repetitive structure coexist. The *longitudinal* is however predominant in the *Vertebrata, Mollusca* and *Articulata,* while the *centrifugal* is greatly developed in the *Cœlenterata* and *Radiata.* In none but the simplest forms, are either of these modes to be found alone.

The *centrifugal* repetition or addition, more nearly resembles the mode of aggregation of atoms in inorganic or crystalline bodies, and hence may be regarded as the inferior manifestation. It implies that growth force in this case conforms to a law of polarity in exhibiting itself at equal distances from a centre,—which is allied to ordinary molecular force, and independent of the localizing influences of which higher organisms seem capable. In centrifugal animals, then, the latter evidently plays an inferior part. In Cœlenterates and Radiates, however, the body possesses a short longitudinal axis, in some (*Asterias*) very short, in others (*Holothuria*), more elongate. The amount of complication of centrifugal growth greatly exceeds the complication in a longitudinal direction in all of these animals except the *Holothurida.*

It is now important to observe that great numbers of centrifugal animals are sedentary or sessile; while the longitudinal are vagrant, moving from place to place. Many of the centrifugal animals which wander, do not do so in in the direction of their axis, but sideways (*Medusæ*). It is also proper to notice that not only the movements of the muscles, but also the direction taken by the food is in the long axis. It is therefore to be concluded that in longitudinal animals growth force has assumed a more truly animal type, and that this tendency has predominated over the polar or molecular tendency.

In most longitudinal animals, however, certain lateral portions, limbs, etc., extend on each side of the axis; and were the space marked by their extremities, and those of the axis, filled, we would have the outline of a centrifugal animal.

Before discussing the influences which have increased and located growth force, it will be necessary to point out the mode in which these influences must necessarily have effected growth. Acceleration is only possible during the period of growth in animals, and during that time most of them are removed from the influence of physical or biological causes, either through their hidden lives or incapacity for the energetic performance of life functions. These influences must, then, have operated on the parents, and become energetic in the growing fœtus of the next generation. However little we may understand this mysterious process, it is nevertheless a fact. Says Murphy, "There is no act which may not become habitual, and there is no habit that may not be inherited." Materialized, this may be rendered—there is no act which does not direct growth force, and therefore there is no determination of growth force which may not become habitual; there is, then, no habitual determination of growth force which may not be inherited; and, of course, in a growing fœtus becomes at once energetic in the production of new structure in the direction inherited, which is acceleration.

But if the forces converted into growth force are derived from without the animal organism, whence and what the agency by which the acceleration or retardation of the latter is inherited from the parent? A few suggestions only on this head can be made in the fourth section.

III. THE LAW OF USE AND EFFORT.

Up to this point we have followed paths more or less distinctly traced in the field of nature. The positions taken appear to me either to have been demonstrated or to have a great balance of probability in their favor. In the closing part of this paper I shall indulge in more of hypothesis than heretofore.

Since repetitive addition only produces identical results in archetypes, and each effort produces results more and more unlike its predecessor as structure becomes specialized; it becomes important to examine into the influences which have originally modified the repetitive efforts successively, producing structures more or less different in detail in the second generation from those of the parents, in acceleration, or the reverse, in retardation.

Going further back, the question arises, why a simple exhibition of repetition (*e. g.*, cell division) should be converted into a complex or duplicated repetition (*e. g.*, jointed ray). This it has already been stated, is one consequence of increased amount of the growth force.

We then seek explanation of the main question, as to what determines the location of this additional or new growth force. (Div. A.)

Lastly, why the total amount of this force should change in a given individual or part of an individual. (Div. B.)

A. ON THE LOCATION OF GROWTH FORCE.

What are the influences locating growth force? The only efficient ones with which we are acquainted, are, first, physical and chemical causes; second, use; and I would add a third, viz: effort. I leave the first, as not especially prominent in the economy of type growth among animals, and confine myself to the two following. The effects of use are well known. We cannot use a muscle without increasing its bulk; we cannot long use the teeth in mastication without inducing a renewed deposit of dentine within the pulp-cavity to meet the encroachments of attrition. The hands of the laborer are always larger than those of men of other pursuits. Pathology furnishes us with a host of hypertrophies, exostoses, etc., produced by excessive use, or necessity for increased means of performing excessive work. The tendency, then, induced by use in the parent, is to add segments or cells to the organ used. Use thus determines the locality of new repetitions of parts already existing, and determines an increase of growth force at the same time, by the increase of food always accompanying increase of work done, in every animal.

But supposing there be no part or organ to use. Such must have been the condition of every animal prior to the appearance of an additional digit or limb or other useful element. It appears to me that the cause of the determination of growth force is not merely the irritation of the part or organ used by contact with the objects of its use. This would seem to be the remote cause of the deposit of dentine in the used tooth; in the thickening epidermis of the hand of the laborer; in the wandering of the lymph-cells to the scarified cornea of the frog in Cohnheim's experiment. You cannot rub the sclerotica of the eye without producing an expansion of the capillary arteries and corresponding increase in the amount of nutritive fluid. But the case may be different in the muscles and other organs (as the pigment cells of reptiles and fishes) which are under the control of the volition of the animal. Here, and in many other instances which might be cited, it cannot be asserted that the nutrition of use is not under the direct control of the will through the mediation of nerve force. Therefore I am disposed to believe that growth force may be, through the motive force of the animal, as readily determined to a locality where an executive organ does not exist, as to the first segment or cell of such an organ already commenced, and that therefore effort is, in the order of time, the first factor in acceleration.

Addition and subtraction of growth force in accordance with the modes pointed out below, account for the existence of many characters which are not adaptive in their nature.

Acceleration under the influence of effort accounts for the existence of rudiments of organs in process of development, while rudiments of organs in process of extinction are results of retardation, occasioned by absolute or complementary loss of growth force. Many other characters will follow, at a distance, the modifications resulting from the operation of these laws.

Examples of the Influence of Physical Causes.

This is nowhere better seen than in the case of coloration, which requires the light of the sun for its production. The most striking examples of this are seen in the colorless surface of animals inhabiting the recesses of caves, as the blind craw-fish and the *Amblyopsis*, etc. If evolution be true, these have descended from more highly colored progenitors. The flat fishes, also (*Pleuronectidæ*) as is known, swim on one side in adult age, but many of them are hatched symmetrical fishes, or nearly so, one eye rotating from one side to the other by a twisting of the cranial bones. It is thus probable that they have descended from symmetrical fishes, which were similarly colored on both sides. Now, the lower side is colorless, the upper retaining often brilliant hues. The influence of sunlight is thus as distinctly discoverable among animals as among plants, where it has been generally accepted as a principal of vegetable physiology.*

Examples of the Effects of Effort and Use.

a The Respiratory and Circulatory System of Vertebrates. It is well known that the succession of classes of Vertebrates is measured first by

*In this and similar cases, care must be taken not to misunderstand the writer by supposing him to mean that in *each generation separately* the peculiar coloration is the result of changed exposure to light. The evolutionist will understand that the effect of such influence increases with succeeding generations by the addition to inherited character, of the effect of immediate external cause.

their adaptation to aëration in water, and then by their successive departures from this type in connection with the faculty of breathing air. The same succession of structure is traversed by the embryos of the vertebrates, the number of stages passed being measured by the final status of the adult. This transition takes place in the Batrachia later in development than in any other class. Now, it is well known that the transition or metamorphosis may be delayed or encouraged by suppression of use of the branchial and encouragement of use of the pulmonary organs or the reverse.

The aquatic respiration of tadpoles may be indefinitely prolonged by preventing their access to the surface, and it is known that in nature the size or age of the larva at time of metamorphosis may vary much in the same species. If perennibranchiates (*Siren e. g.*) are deprived of their branchiæ, they will aërate blood by the lungs exclusively, and there is no reason to doubt that by use of these, and disuse of the branchiæ, aërial respiration might become the habit of the animal. It is also easy to perceive that geologic changes would bring about a necessity for precisely this change of habit. This occurred in the period of the coal measures, where large fresh water areas were desiccated, and it was precisely at this period that many air breathing Batrachians originated and had a great development.

β *The rattle of the Rattlesnake.*

Nearly all of the larger harmless snakes which live on the ground have a habit of throwing the end of the tail into violent vibrations when alarmed or excited, with the view of alarming a supposed enemy. Among *Coronelline* snakes, *Ophibolus triangulus* possesses it; among the water snakes, *Tropidonotus sipedon*. In the typical Colubrine group the black snake, *Bascanium constrictor* is an example; *Pityophis sayi* also shakes the tail violently. The copperhead (*Ancistrodon contortrix*) and the moccasin (*A. piscivorus*) (fide Günther) have the habit in a marked degree. Among the rattlesnakes it is a means of both warning and defence, in connection with the rattle which they carry.

In the structure of the end of the tail of harmless snakes, we see a trace of the first button of the rattle in a horny cap that covers the terminal vertebræ.

In the venomous genera, it is conspicuous in *Lachesis* especially, reaching a considerable length and having a lateral groove. In the plate-headed rattlesnakes (*Crotalus*) this corneous cap is inflated into a button with lateral groove, and in some of them possesses only one or two buttons or joints. In the perfected rattlesnakes (*Caudisona*) not only are the segments numerous and inflated, but a number of the terminal caudal vertebræ are greatly enlarged vertically, and coössified into a mass.* This is important from the fact that the rattlesnakes are the most specialized of all snakes, standing at the head of the order, and as such, on the principal of *acceleration* present the greatest amount of *grade nutrition.*

Now it appears to me, that the constant habit of violent vibration in a

*See good figures of this structure in Zeitschr. f. Wissensch. Zoologie, VIII, Tab. 12.

part, tends to determine an increased amount of nutritive fluid to it, in other words to localize growth nutrition, and when this has attained complex repetition or grade nutrition, to result in new grade structure. (The segments of the rattle being nearly all alike, it is a case of simple repetition.) This view appears to be as reasonable as that generally entertained with regard to the cause of spavin in the horse's leg. Here, owing to excessive use, exostoses appear on the bones surrounding the tibio-tarsal articulation. As to the reason of the structure in question not appearing in forms lower in the scale than the rattlesnake, it is explained below, if the law of accumulation of grade nutrition be true. (See sec. B.) This is, that repetition (or acceleration) is only possible where the animal has an excess of growth force at its disposal, or can abstract it from some portion which is unused or useless.

γ *On horns.* The possession of horns on the posterior part of the cranium, as defenses against enemies is a character found in many distinct types of animals. (Herbivora have no (dental) weapons and need horns). It is seen in the *Batrachia Stegocephala* in the extinct genus *Ceraterpeton;* among *Anura* it is approached by *Triprion* and *Hemiphractus.* Among Reptilia it is well marked in *Phrynosoma,* a Lacertilian genus. In *Mammalia* the *Artiodactyla Ruminantia* are the horned animals of the order. We have opportunities of observing the habits of these representatives of the Frogs, the Lizards and the Mammals.

In the first case, any one who has kept ordinary toads and tree toads in confinement, is aware that when attacked and unable to escape, they defend themselves by presenting the top of the head forwards and using it as a shield. Now I have already pointed out* that in both toads, tree toads, and frogs, there are natural series of genera, measured by the degree of ossification of the superior cranial walls, the longest being that of the Hylidæ, which embraces six terms, viz: *Hylella, Hyla, Scytopis, Osteocephalus, Trachycephalus* and *Triprion.* The two last have the head thoroughly shielded, and *Triprion* has projecting angles which appear in some South American forms lately described by M. Espada, to be developed into short horns. That this excessive ossification is associated with the habit of protecting the whole body with the front, seems likely.

In the case of *Phrynosoma* we know that precisely the same habit is associated with the presence of the sharp horns; and that some genera without horns possess it also. *Phrynosoma* is an exceptionally sluggish genus in a family of most active forms, and must necessarily resort to this mode of defence more than they.

In the case of Ruminants, we also know that defence is accomplished by throwing the head down with the horns thrown forwards. But this is not confined to this group. That generalized suborder, the *Artiodactyla Ordinaria,* represented by the hog, which were no doubt the genetic predecessors of the Ruminants in time, also throw the head down in defence in the same way, having thus a manner totally distinct from that seen in

*Origin of Genera, 1868, p. 14.

the *Carnivora*. The latter show their *teeth* and often crouch preparatory to a leap.

These cases present so constant an association between habit and use, that admitting evolution, we are compelled to believe that the structure has given rise to the habit or the habit to the structure. In the former case, we have to suppose, with the author of natural selection, that among the many spontaneous variations, rudimental horns occasionally appeared, and that their possessors being thus favored in the struggle for existence, were preserved and multiplied; while those not favored, dwindled and were ultimately nearly all extirpated or starved. The question of origin is here left to chance, and Alfred Bennett has made a mathematical estimate of the chances of any particular profitable variation occurring among the great number of possibilities of the case. This has shown the chance to be so excessively small as to amount in most cases to a great improbability.

If we turn to the probabilities of such structure having arisen through the selection of that mode of defence by the animal, we find them greatly increased. The position occupied by the horns, in all the animals described, is that which is at once brought into contact with an enemy in conflict, and as sport among animals is a gentle imitation of conflict, the part would be constantly excited in sport as well. With an excess of growth nutrition, our knowledge of the effects of friction on the epidermis, and of excessive ligamentous strain and inflammation on bone (*e. g.*, spavin in horses) as well as of abnormal exostoses in general, would warrant us in the belief that the use of the angles of the parts in question in these animals, would result in a normal exostosis, of a simple kind in the frogs, or as horn cores in the Ruminantia. As to the sheathing of the cores in the *Bovidæ*, and nakedness in the *Cervidæ*, it is in curious relation to their habitat and to their habits. The epidermis and derm would of course share in the effects of friction. In the Bovidæ which dwell in treeless plains, or feed on the grasses in great part, the development of these coverings of the horn cores into a horny sheath, would naturally meet with no interruption. In the case of the deer, which mostly live in forests or browse on trees, constant contact with the latter would prevent the healthy growth of the dermal covering, and it would be liable to injury or constant excoriation by the animals themselves on the branches of trees, etc. This we know to be the present habit of the deer as regards the dermal covering of the horns. I have elsewhere pointed out the similar connection between the dental structure and habitat among the oxen and the deer. The former eating the harder grasses, are provided against the consequent rapid attrition of the tooth, by a prismatic form, which allows of more prolonged growth and more rapid protrusion. The deer, in accordance with their foliage-eating habits, do not wear the crown of the tooth with such rapidity. Long continued protrusion is not so necessary, hence the teeth are more distinctly rooted and have a prominence or shoulder, distinguishing the body of the crown.

B. Change in Amount of Growth Force.

1. *Absolute increase of Growth Force.*—As every type has had its period of greatest development in numbers, size, and complication of structure, the present law indicates as an explanation, a culmination of the process of conversion of growth force from its energetic to its potential state in tissue. The cause is primarily the increased exercise of effort and use, which while effecting a conversion, increases the capacity of the organs by which further conversion is effected.

2. *Local increase of Growth Force.*—Examples of a local increase of this kind are probably to be seen in convoluted organs; as the convolutions of the brain in higher Mammalia; the convolutions of the enamel of the Labyrinthodont Batrachia; the same phenomenon in the cotyledons or plumule of some seeds. In these cases the superficial area of the parts is excessively developed, and the inclosing organs not being proportionately enlarged, a convolution necessary follows. In the first case, the skull; in the second, the alveolus; in the third case, the seed-envelope, restrain the expanse of the contained part, which would otherwise follow increase of growth force.

3. *Absolute loss of Growth Force.*—This will follow defective nutrition, produced by inability of the animal to obtain heat and food requisite to that end. This is supposed to be due (according to the view hereafter proposed) primarily to deficiency of intelligence, in failing to adapt habits to changed physical circumstances, and secondarily to the unfavorable influence of such changed circumstances. The extinction of highly specialized types, which has closed so many lines of animal types, will be accounted for by their less degree of plasticity and want of capacity for change under such changed circumstances. Such changes consist of modified topography and temperature, with irruptions of many new forms of life by migration. The less developed forms would be most likely to experience modification of structure under a new order of things, and palæontology teaches that the predecessors of the characteristic types of one period were of the less specialized forms of that which went before.

Thus is explained the fact that, in following out the line of succession of animal forms we have constantly to retrace our steps from specialized extremes, (as osseous fishes, tailless Batrachia, song birds, etc.), to more generalized or simple forms, in order to advance beyond.

4. *The complementary diminution* of growth nutrition follows the excess of the same in a new locality or organ, of necessity, if the whole amount of which an animal is capable, be, as I believe, fixed. In this way are explained the cases of retardation of character seen in most higher types. The discovery of truly complementary parts is a matter of nice observation and experiment. Perhaps the following cases may be correctly explained.

A complementary loss of growth force may be seen in absence of superior incisor teeth and digits in ruminating Mammalia, where excessive force is evidently expended in the development of horns, and complication of stomach and digestive organs. The excess devoted to the latter region may account for the lack of teeth at its anterior orifice, the mouth; otherwise, there appears to be no reason why the ruminating animals should not have the superior incisors as well developed as in the odd toed (Perissodactyl) Ungulates, many of which graze and browse. The loss to the osseous system in the subtraction of digits may be made up in the development of horns and horn-cores, the horn sheath being perhaps the complement of the lost hoofs. It is nct proposed to assert that similar parts or organs are necessarily and in all groups complementary to each other. The horse has the bones of the feet still further reduced than the ox, and is nevertheless without horns. The expenditure of the complementary growth force may be sought elsewhere in this animal. The lateral digits of the *Equidæ* are successively retarded in their growth, their reduction being marked in *Hippotherium*, the last of the three-toed horses; it is accompanied by an almost coincident acceleration in the growth nutrition of the middle toe, which thus appears to be complementary to them.

The superior incisors of the *Artiodactyla* disappear coincidentally with the appearance of horns, which always exist in the toothless division of the order, except in some very small antelopes (*Cephalophus*, etc.) where the whole amount of growth force is small. Possibly the superior incisors and horns are complementary here. The retardation in development of the teeth in the higher apes and men, as compared with the lower apes is coincident with the increase of number of brain convolutions. That this is not necessarily coincident with reduction of teeth in other groups is plainly proven by the rodents and *Chiromys* where the loss of many teeth is complementary to the great size of the incisors of the middle pair. But in man there is no complementary increase of other teeth, and the reduction is no doubt due to contraction of the jaws, which is complementary to increase in other parts of the cranium, in both apes and men.

I am confident that the origin and loss of many structures may be accounted for in this way, and the correlation of parts to each other be *measured* accurately.

Objection. The first one which arises is that which the author of the Vestiges of Creation made against Lamarck's theory of a similar kind, *i. e.* that by assuming that effort, use and physical causes have originated modifications of structure, we give the adaptive principle too much to do. I have made the same objection to the theory of natural selection. It is true that an application to a purpose is involved in the present theory of the "location of growth force;" but in point of fact, a large number of non-adaptive characters are accounted for by it. These are the rudimental and transitional ones which mark the successive steps preliminary to the completion of an adaptive structure; second, those produced by deficiency of growth force in less favored regions of the body, and third and fourth, phenomena consequent on general deficiency and excess of growth force.

And it may be said in conclusion that if the three principles, or if use especially, should be found to be inadequate to the service here demanded of them, it may be at least said that they or the last named, constitute the only controllers of growth force to any degree at all, with which we are acquainted.

IV. ON GRADE INFLUENCE.

The object of the present section is the attempt to discuss how the influence of effort and use on the parent is placed in a position to be inherited by the offspring.

A. Of the Nature of Grade Influence.

In the first place, it is necessary to note the definition and character of grade influence.

α. Growth force uninfluenced by grade influence simply adds tissue either (*a*) in enlarging size, or (*b*) in replacing waste. It does this by repeating the cell, by division, in localities which have already assumed their specific form. This form of growth force may persist throughout life, but with diminished energy in age.

β. Grade influence directs growth force in building up the tissues into organs, and constructs the parts of the body successively to completion, the result expressing the type or grade of the animal or plant. Its energy terminates with maturity, except in cases of periodical reproduction of sexual ornaments of the male (birds, deer), where it continues throughout life, appearing at regular intervals.

But it has occurred in acceleration that instead of a simple repetition of the ultimate histological element of an organism, in adding to its amount, it adds a completely organized part of the structure, as a tube, a phalange, a digit, a limb or an arch; an ocellus or a tooth. For instance, in the genus *Amblystoma*, one section possesses four phalanges on the longest digit; another section exhibits but three. In the species *A. mavortium*, some individuals have the small number of phalanges, but the majority possess the larger number. As all are of common parentage a whole phalange has been lost or added. The explanation of this phenomenon is essential to the comprehension of the *origin* of type structures.

*In plants, growth nutrition continues throughout life, but in the higher plants it is more active during the earlier years in perennial species, additions to size becoming less and less marked with increasing age. Grade nutrition also persists, throughout life, but is chiefly active during a short period only of every year, or during flowering and fruiting. Not only in the production of the reproductive organs, but also in the yearly additions to other typical parts of the plant, grade-nutrition is active.

**In animals, growth nutrition is more active in the early stages of life, but is continued throughout in the lower divisions; in the highest, it is also continued throughout life, but there is a greater contrast between its results during youth, when nearly the whole size is attained, and during age, where the additions are much less.

Grade nutrition is, on the other hand, entirely confined to infancy and youth, except in those low animals which produce their reproductive organs periodically (some *Entozoa*, etc.), where it may be said to be in nearly the same condition as in plants.

γ While the amount of growth force, potential in adult living animals, has varied very irregularly throughout the animal kingdom, there being large and small, simple and complex, in every division, it would seem to have accumulated on the whole, with the rising scale of animal types. Thus the lower or *Protozoa* are the smallest; *Radiates* are next in size; *Molluscs* and *Articulates* reach nearly the same maximum, which exceeds that of the *Radiates*, and falls far below that of the *Vertebrates*. Among the last the mammalia have attained as large if not larger size than any of the other orders (*e. g.*, *Cetacea*). This is, however, not necessary to the history of evolution.

That an increased amount of grade growth force has been constantly rendered potential, during the advance of time is clear, if the preceding inferences be true. It is also evident that some individuals have accumulated it more rapidly than others, if all alike originated from the simplest forms known to us. Multitudes have remained in the earliest stages (*Protozoa*) of the whole series, or of their own special series (*Lingula*), forming "persistent types;" or taken directions which rendered them incapable of expansion beyond a certain point without exhaustion or death; for example, complicated types, as *Ammonitidæ*. The quadrumanous animal which was the progenitor of man, may thus be believed to have acquired a higher capacity of this accumulation than his cotemporaries.

Assuming the nucleated cell to be the ultimate element of organic tissue, there are two types of life in which grade influence has not appeared, viz.: unicellular animals and plants, and living forms composed of homogeneous protoplasm. In the latter neither grade influence nor animal growth force is potential; in the former, simple growth force only. It is therefore apparent that grade influence has been developed in the organism itself; perhaps this may have been, in the plant, through the modified influence of external physical causes; in the animal, if our inductions as to use and effort be true, under the influence of the activities of the parent, which determined a structural change either in itself or in its offspring. The possibilities of this origin are considered in the next section.

δ. The *Location of Growth Force* proceeds under the direction of what Professor Henry calls "Vital influence." With this author I discard the use of the term "Vital Force," what was originally understood by that term being a complex of distinct ideas. The *Vital forces* are (nerve force) *Neurism*, (growth force) *Bathmism*, and (thought force) *Phrenism*.* All

*The objection of President Barnard to thought being an exhibition of a force, is that "thought cannot be measured." This objection does not take into consideration the two-fold nature of thought. The *amount* of thought can most assuredly be measured, the *quality* of the thought, in one view of the case, cannot. That part which cannot be measured is that which determines the *Location of thought force*, which, as in the case of growth force, is an attribute of the vital or other principle.

of these are supposed to be correlated to the Physical Forces, but are under direction and control of the *Vital principle* which locates their action, etc., just as molecular or *atomic constitution* determines the locality and character of the physical forces. The laws of the vital principle and of atomic constitution also determine the nature of the conversion of one force into another. Now, since physical and vital forces are correlated and convertible, the close relationship of the two controlling principles becomes obvious, and suggestive of their identity.

Dr. Carpenter, in describing the correlation of physical and vital forces, defines the difference of organic species to be similar to that prevailing between different chemical bodies (the latter depending on different molecular and atomic constitution), which leads them "*to behave* differently" from each other under similar circumstances. This may be more fully expressed by saying that different species possess different capacities for the location of the conversion of the physical forces into growth-force. A "descent with modifications" contemplated by a process of evolution, signifies a progressive change in this capacity. *Acceleration* means an increase in this capacity; *retardation* a diminution of it. *Grade influence* means the influence which has produced this change of capacity.

Precisely what the change consists in is a mystery, but that it is material in its character is rendered more probable the more we examine it.

B. The Origin of Grade Influence.

Living protoplasm can convert heat and nutriment into growth force without the agency of the nervous system. This is proven by the nutrition of the *Protozoa* and *Cœlenterata* and from experiments on the muscles of frogs, etc. In the latter case, as is well known, the nerve may be divided, and the muscle retain its size if a current of electricity be passed through it, thus sustaining the nutrition. As the presence and structure of the nervous system is in relation to the specialization of animal structure in other respects, it is very probable that the nervous system is in *higher* animals the agent of the *location* of growth force. In the lowest it is not effected by any such means. As the nervous system is the instrument of the metaphysical peculiarities of the animal (emotions, choice, etc.), we may conclude that in the lower animals, location of growth force is influenced by necessity without choice; in the higher by necessity with choice.

The impulses derived from the nervous system, it is known, may be reflex or automatic in consequence of application of stimuli from without. They may become so also, after having been originated consciously or by effort of will. In the case of habits, frequent exercise of choice has so impressed the nervous system as to result in its repetition of effort, often in opposition to changed choice.

The influence of effort in muscular action on the nervous system appears to be, first, to enable it to convert heat to nerve force, and, then, to conduct nerve force to the involuntary muscles or those controlling circulation, where it is converted into motion, which thus controls nutrition through circulation. The nervous system, like others, develops in capacity with use, hence probably nerve tissue converts heat into nerve force as muscular tissue converts heat into motion. In other words, by repetition, the capacity of the nervous system for this conversion of heat is known to increase. As the amount of heat converted is in proportion to the amount of appropriate nerve tissue (see above) it is evident that use and effort increase the amount of nerve tissue.

The phenomena of thought render the same modification of structure probable. Effort in the direction of thought is supposed to convert heat into thought force. Inasmuch as the more intelligent animals possess the highest development of cerebral hemispheres, it is highly probable that brain substance converts heat into growth force also, which produces tissue of its own kind precisely as muscle does.

As different parts of the nervous centres, subserve different purposes, the development of these parts must proceed approximately under the influence of special kinds of effort and use. Where, as in the adult, heat is converted into growth force in the tissues to a very limited extent, if the above principles be true, the conversion of heat by the nervous system into nerve growth force and tissue, is on the other hand, not terminated.

Capacity for effecting conversion of force is regarded, as above pointed out, as dependent on molecular constitution. Hence we conclude that change in that capacity on the part of the nervous system involves a molecular change in its constitution.

Now, it is apparent that if the nervous centres possessed the enlarged capacities for the conversion of heat into nerve force and thus of constantly controlling the circulation in special directions, in a growing or fœtal animal, tissue will be produced in the directions in question. For the heat converted into motion in the adult is in the fœtus in large part converted into growth-force.

Now, we know physical and metaphysical peculiarities of parents to be inherited by offspring, hence, no doubt, the nervous structure determinative of growth force is inherited. This will then control the localities of special conversion of heat, etc., (from the mother) into growth force, in accordance with the structure of the parent, and the more decidedly, as its own increase progresses.

The result will be *acceleration*, or construction of tissues and organs in excess of those of the parent, if the effort or use devoted to a nerve or organ be represented in the nerve centre of the parent by a greater amount of force-converting tissue, than is necessary when iuherited in the fœtus for the construction (by conversion), of tissues and organs like those of the parent.

That this is a partial explanation of inheritance, is rendered probable from the fact that, the types of structure presented by the nervous centres, express the grade of the animals possessing them far more nearly than those of any other organ or set of organs. If the brain, like other organs, develops by intelligent use, it cannot be doubted that this relation of its development to grade is not accidental, but that grade structure is an expression of its capacities, physical and mental.

C. On the Transmission of Grade Influence.

How force potential in nerve structure is inherited through the reproductive elements is a great mystery. The following considerations relate to it.

1. Secre'ion is known to be conducted through the conversion of heat into growth force, probably through the intervention of nerve force.

2. In many secretions which possess strong chemical qualities, as gastric juice, bile, saliva, etc., the fluid is formed by a destruction of the cells representing the efforts of growth force, which is therefore no doubt converted into chemism or chemical force.

3. In the spermatozoöids, which are produced by a process of secretion, the cells are not destroyed, and thus growth force remains potential; they exhibit however lively motions, which may represent motive force derived from the nervous centre.

4. While in contact with the yolk of the ovum, so long as vitality lasts, the motion must be communicated to portions with which it is in contact, or converted into one of the forces from which it was derived (heat) or into another force (growth force). The growth force potential in the cell of the spermatozoöid, on its destruction, becomes converted into heat or other force. Thus may originate the growth force of the ovum, which, once commenced, is continued through the period of growth. The process might be compared to the application of fire to a piece of wood. The force conversion is communicated to other material than that first inflamed. The new fuel in the case of the embryo, is the protoplasm derived from the mother.

V. ON INTELLIGENT SELECTION.

As neither use nor effort can be ascribed to plants, and as we know that their life history is much more dependent on their surroundings, than is that of animals, we naturally look to the physical and chemical causes as having a prime influence in the origination of their type structures. Without greater familiarity with the subject, I will not attempt to say how far the various degrees of growth force possessed by parent plants, located under the influence of meteoric and other surroundings, and preserved, destroyed or restricted by natural selection, may account for the characters of their successors of the present period. But other agencies similar to use, that is, automatic movements, may be also introduced as an element in the argument. The movements of tendrils seeking for support may be here considered, and as Dr. Asa Gray has pointed out, have consequences similar to those of use in animals. When the tendril seizes a support, growth force is located at the point of contact, for the tendril increases considerably in thickness.

Among animals of the lowest grade, movement must be quite similar to those of plants, or automatic from the start, and not even at the beginning under the influence of will. Evidence of will is, however, soon seen in the determinate movements of many of the Protozoa in the seizing of food. With *will* necessarily appears a *power of choice*, however limited in its lowest exhibitions, by the lack of suggestive metaphysical qualities, or the fewness of alternatives of action presented by surrounding circumstances, to animals of low and simple organism. We can, however, believe that the presence of greater or less number of external facilities for action, characterize different situations on the earth's surface, as well as that greater and less metaphysical capacity for perceiving and taking advantage of them, must exist in different individuals of every species of animal, however low, which possesses consciousness and will. These qualities will, of course, influence effort and use to the advantage of the animal, or the reverse.

Effort and use have very various immediate stimuli to their exertion.

Use of a part by an animal is either compulsory or optional. In either case, the use may be followed by an increase of nutrition under the influence of reflex action or of direct volition.

A compulsory use would naturally occur in new situations which take place apart from the control of the animal, where no alternatives are presented. Such a case would arise in a submergence of land where land animals might be imprisoned on an island or in swamps surrounded by water, and compelled to assume a more or less aquatic life. Another case which has also probably often occurred, would be when the enemies of a species should so increase as to compel a large number of the latter to combat who had previously escaped it.

In these cases, the structure produced would be necessarily adaptive. But the effect would sometimes be to destroy or injure the animals (retard them) thus brought into new situations and compelled to an additional struggle for existence, as has, no doubt, been the case in geologic history.

Direct compulsion would also exist where alternatives should be presented by nature, but of which the animal would not be sufficiently intelligent to take advantage.

Most situations in the struggle for existence, afford alternatives, and the most intelligent individuals of a species will take advantage of those most beneficial. Nevertheless, it is scarcely conceivable that any change or increase of effort, or use, could take place apart from compulsion derived from the relation of external circumstances, as a more or less remote cause.

Preservation, with modifications, would most probably ensue when change of stimulus should occur gradually, though change of structure might occur abruptly, under the law of *expression points*.*

Choice is influence not only by *intelligence*, but by the *imagination* and by the *emotions*.

Intelligence is a conservative principle, and always will direct effort and use into lines which will be beneficial to its possessor. Here we have the source of the fittest—*i. e.*, addition of parts by increase and location of

* See origin of Genera, p. 38.

growth force, directed by the will—the will being under the influence of various kinds of compulsion in the lower, and intelligent option among higher animals.

Thus, intelligent choice taking advantage of the successive evolution of physical conditions, may be regarded as the *originator of the fittest*, while natural selection is the tribunal to which all the results of accelerated growth are submitted. This preserves or destroys them, and determines the new points of departure on which accelerated growth shall build.

The influences locating growth force, may be tabulated as follows :

Division.	*Influence.*					
Plants..	Physical and chemical.	+ ? ?				
Plants with mechanical movements; animals with indeterminate movements.	"	+ use				
Animals with determinate movements or will, but no intelligence.	"	"	+ effort under compulsion.			
Animals with will and less intelligence.	"	"	"	"	+	choice.
Animals with more intelligence.	"	"	"	"	+	intelligent choice.

As examples of intelligent selection, the modified organisms of the varieties of bees and ants must be regarded as striking cases. Had all in the hive or hill been modified alike, all soldiers, neuters, etc., the origin of the structures might have been thought to be compulsory; but varied and adapted as the different forms are to the wants of a community, the influence of intelligence is too obvious to be denied. The structural results are obtained in this case by a shorter road than by inheritance.

The selection of food offers an opportunity for the exercise of intelligence, and the adoption of means for obtaining it, still greater ones. It is here that intelligent selection proves its supremacy as a guide of use, and consequently of structure, to all the other agencies here proposed. The preference for vegetable or for animal food determined by the choice of individual animals among the omnivores, which were, no doubt, according to the palæontological record the predecessors of our herbivores, and perhaps of carnivores also, must have determined their course of life and thus all their parts, into those totally distinct directions. The choice of food under ground, on the ground, or in the trees would necessarily direct the uses of organs in the appropriate directions respectively.

In the selection of means of defence a minor range of choice is presented. The choice must be limited to the highest capabilities of the animal, since in defence, these will, as a general thing, be put forth. This will, however, not be necessarily the case, but will depend in some measure on the intelligence of the animal, as we readily observe in the case of domesticated species.

In the case of the rattlesnake, already cited, the habit of rapid vibration of the tail, appears to me to be the result of choice, and not of compulsion. For the cobra, of India, for the same purpose, expands the anterior ribs, forming a hood, which is a very different habit. Here are two alternatives, from which choice might be made, and violent hissing is a third, which the species of the colubrine genus *Pityophis*, have adopted to some purpose. As to the benefit of the rattle, it no doubt protects the animal from all foes other than man; but is rather a disadvantage as regards the latter, being by a beautiful turn of events a protection to the higher animal.

On the principal of natural selection it might be supposed that the harmless snakes which imitate the Crotalus for the sake of defence were preserved; but if the above explanation of the origin of the habit in the latter be true, the second explanation is not valid.

The power of metachrosis, or of changing the color at will, by the expansion under nerve influence of special pigment cells, exists in most *Reptilia*, *Batrachia* and fishes. It is then easy to believe that free choice should, under certain circumstances, so habitually avoid one or another color as to result finally in a loss of the power to produce it.

Thus, it appears to be a fact, that not only are species of fishes which dwell in the mud, of darker hues than those that inhabit clear water, but that individuals of the same species differ in a similar manner in relation to their habitats, those that live in impure or muddy waters having darker tints than those of clear streams.

Land animals present equally abundant and remarkable imitations of the objects or substances on which they live. This is well known in insects and spiders, which look like sticks or leaves, or the flowers on which they feed. It is seen in reptiles, which in very many cases can voluntarily assume the hue of leaf, stone or bark, or have constantly the gray color of their native desert sands.

These cases are largely selective or optional in their origin, for though metachrosis is also induced by some external stimulus, as an enemy or a food animal, yet other means of escaping the one and procuring the other, are generally open.

These facts pave the way for a consideration of the phenomenon of mimetic analogy which, though well known to naturalists, may be illustrated by the following new facts:

On the plains of Kansas, there is a species of *Mutilla* whose abdomen and thorax are colored ochraceous or brown-yellow, above. A spider of the genus *Salticus* is equally abundant, and is almost precisely similar in the color of the upper surfaces, so much so as to deceive any but a most careful observer. The *Mutilla* being a well armed insect, and a severe stinger, there can be no doubt that the *Salticus* derives considerable immunity from enemies from its resemblance.

On the same plains, the *Caudisona confluenta*, or prairie rattlesnake abounds. It is an olive grey, with a series of transverse brown dorsal spots, and two rows of smaller lateral ones. The head exhibits a number of brown and white bands. The prairie *Heterodon*, (*H. nasicus*) possesses not only the same tints but the same pattern of coloration, and at a short distance cannot be distinguished from it.

In consequence, as one may justly say, this species is, with the rattlesnake, the most common serpent of the plains, as it shares, no doubt, in the protection which the armature of the *Caudisona* gives its possessor. This is in accordance with the views of Wallace and Bates.

A curious case occurred to me in four species of fishes, which I took in a small tributary of the Yadkin River, in Roane County, N. C. Among several others, there were varieties of the widely distributed species *Chaenobryttus gillii*, *Hypsilepis analostanus* and *Ptychostomus pidiensis*, (each representing a different family), which differ from the typical form of each in the same manner, viz : in having the back and upper part of the sides with longitudinal black lines, produced by a line along the middle of each scale. This peculiarity I have not observed in these species from any other locality. Until I had examined them I thought them new species.

The only other species presenting such marking in the Yadkin River, is the large perch, the *Roccus lineatus*. According to the theory of natural selection a resemblance to this well armed species might be of advantage to the much weaker species in question ; yet the same species co-exist in other rivers without presenting the same mimicry.

It is difficult not to urge the importance of the causes already regarded as efficient in the origination of structure, in the present branch of the subject also. We are especially disposed to call in use and effort here, after noticing how much more distinctly change of color is under the control of the animal, than change of shape. It must, however, be borne in mind that similar resemblances exist among plants ; though, as Prof. Dyer shows, a large majority of these cases occur in species of different floral regions. Thus in this case, as in those of structure already cited, we appeal first to physical laws in the lowest beings, but with the increasing interference of use, effort aud intelligence, as we rise in the scale. Thus it is that in the Vertebrates generally, the mimetic resemblances are found in species of the *same region*, where only an intelligent or emotional agency could be illustrated. If among animals as low as butterflies the influence of intelligence be denied, that of admiration for the beauty, or fear of the armature, of the predominant species imitated, would appear to be sufficient to account for the result. Admiration and fear are possessed by animals of very low organization, and with the instincts of hunger and reproduction, constitute the most intense metaphysical conditions of which they are capable. But our knowledge of this branch of the subject is less than it ought to be, for animals possess many mental attributes for which they get little credit.

It appears to be impossible to account for the highest illustrations of mimetic analogy in any other way, the supposition of Wallace that such forms must be spontaneously produced, and then preserved by natural selection, being no explanation. It has been shown by Bennett that the chances of such modification arising out of the many possibilities are exceedingly small.

If the above positions be true, we have here also the theory of the development of intelligence and of other metaphysical traits. In accordance with it, each trait appropriates from the material world the means of perpetuating its exhibitions by constructing its instruments. These react by furnishing increased means of exercise of these qualities, which have thus grown to their full expression in man.

CRITIQUE.

1. *On the preceding essay.*—There will probably be found to be considerable resemblance and coincidence between the theory of Use and Effort, and the Lamarckian view of Development. The writer has never read Lamarck in French, nor seen a statement of his theory in English, except the very slight notices in the Origin of Species and Chambers' Encyclopædia, the latter subsequent to the first reading of this paper.

Darwin's only speculations as to the *origin* of new structures which are contained in his "Origin of Species" (Ed., 1860), so far as I can find, occur in the first and fifth chapters. In the first he says, discussing the variability of domesticated animals and plants, "I think we are driven to conclude that this greater variability is simply due to our domestic productions having been raised under conditions of life not so uniform as, and somewhat different from, those to which the parent species have been exposed under nature. There is also, I think, some probability in the view propounded by Andrew Knight that this variability may be partly connected with excess of food. * * * But I am strongly inclined to suspect that the most frequent cause of variability may be attributed to the male and female reproductive elements having been affected prior to the act of conception. * * Nothing is more easy than to tame an animal, and few things more difficult than to get it to breed freely under confinement, even in the many cases where the male and female unite," etc. Chapter V. repeats similar propositions but states that the effect of climate he believes to be small, but rather greater in plants than animals.

The view as to the impressibility of the reproductive element is taken up by Mivart, but the subject remains in the chaos of unshaped hypotheses.

2. *On the Origin of Genera.*—The memoir issued by the writer under the above name was chiefly devoted to the demonstration of the law of Acceleration and Retardation. A small portion was devoted to geographical and geological relations. It remains to correct two errors in the former portion of the book.

(1). It is there stated (p. 5) that the Law of Natural Selection of Darwin is as follows: "That the will of the animal applied to its body in the search for means of subsistence and protection from injuries, gradually produces those features which are evidently adaptive in their nature.

That in addition, a disposition to a general variation, on the part of the species, has been met by the greater or less adaptation of the results of such variation to the varying necessities of their respective situations. That the result of such conflict has been the extinction of those types that are not adapted to their immediate or changed conditions and the preservation of those that are."

It is unnecessary to state that the first sentence of the above does not express the theory of Darwin in any part or particular, while the two following do.

Further, it is stated (same page), "What we propose is, that of [generic characters] comparatively very few, in the whole range of animals and plants, are *adaptations* to external needs of forces, and that of specific characters a large proportion is of the same kind. How, then, could they owe their existence to a process regulated by adaptation?" Below, it is again said, "that while Natural Selection acts by the 'preservation of the fittest,' Acceleration and Retardation act without any reference to fitness at all; that instead of being controlled by fitness it is the controller of fitness."

Thus, from the existence of large numbers of non-adaptive characters I was induced to believe that an antagonism existed between the two laws. The present essay shews this to have been an error, and that by reconciling them, they become coördinate factors in producing the result. Thus "Acceleration and Retardation" is the "controller of fitness," because all adaptive structures are produced in accordance with it, and in no other way. The law of Intelligent Selection also prescribing fitness, removes it from the domain of physical or material necessity implied by Darwin's law of "Survival of the fittest." Adaptation therefore is the guide of change, though not the mechanically produced adaptation implied by natural selection. The disturbance of the balance of forces produced under its influence, leaves *growth force* to create primarily, the great number of unadaptive characters, which are simply *unfinished adaptive* ones, and secondarily, others occasioned by excess or loss of force in different directions.

The reconciliation of these laws and their complementary relations were perceived before the essay was completed, see in the recapitulation. Prop. II., p. 79.

(2.) Under the head of Heterology (p. 55), a number of groups are introduced as "Homologous" (as defined p. 54). Some of these I believe to be truly of this character, but some others are probably not so related, but are merely series of genera presenting similar structural peculiarities as consequences of the operation of identical laws. I would place under this head, and withdraw from the homologous class, the families of *Lacertilia Leptoglossa*, *Diploglossa* and *Typhlophthalmi*, those of the Old and New World *Quadrumana* and those of *Cephalopoda*.

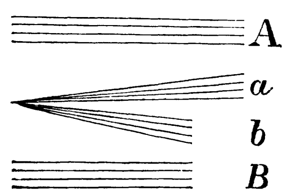


Fig. 13. (See p. 233.)