COÖPERATION AS A FACTOR IN EVOLUTION.

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I.

Evolution is the summation of power through coöperation. For evolution, so far as a science of relative measurements can estimate, is a process of self-maintained growth, or progressive creation; and coöperation, which is the joint action of discrete powers in a common service, is the only knowable way of creating new things and new kinds of power. It is the coöperative action, for example, between atoms, or cells, or organs, or human beings, that creates the new and larger units, called molecules, or individuals, or organisms, or society, all of which are endowed with powers different in quantity and in quality from those of their constituent parts. These larger units, with their appropriate powers, then constitute the ways and means for further coöperative action and for the creation thereby of still larger units with new creative powers.

The duration and progress of evolution depends on the attainment of a fundamental righteousness in the methods of coöperation, the "right" methods being attained by "accident," by "trial and error," and by "design." The process, in any case, is inevitably accumulative, or a process of growth, because of the inherent creative and saving power of coöperation.

Any change in the existing methods of coöperation either checks, or accelerates, the rate of evolution, or modifies its direction, the result depending on the creative value of the change.

Given equal time and opportunities, the degree of progress, or the length of the genetic line, indicates the creative value of the methods of coöperation that were used to attain the result. The methods of internal organic coöperation of the animal, for example, have yielded incomparably higher products than those of the plant, although one has had the same length of time for development, and the same opportunities in the world at large, as the other. On the other hand, the prevailing methods of coöperative action between the plant kingdom and the animal kingdom are essential factors in the evolution of life as a whole, and in the creation of the highest products of both kingdoms. Hence our estimates of values will vary with our visual angle; that is, according as we consider each method or individual by itself, and as an end in itself, or as several different methods, or individuals, acting together for a larger end.

As the vertebrate has progressed farther in the same time and in the same general surroundings than the plant, or than the starfish, or the snail, it is well to inquire what are the basic methods of structure and organization on which this progress depends.

In such an inquiry, we may confine our attention to the internal structure of the individual organism, ignoring, for the time being, its external environment; for, in the main, the external environment is a common factor, affecting all kinds of life in the same way; any special response of the individual to its environment is due to the special structure and special internal life of that individual.

The external environments, for example, of the dog and his master, of father and son, of the bee and the flower, may be essentially the same, but these environments will not affect all their residents in the same way. The things in them that coöperate with the life of one may have no existence in the life of the other because the inner structure and response of the one to the other is different.

Thus while the initial source of our knowledge of living things is external, as our knowledge of these things deepens, it tends to express itself more and more in terms of their inner mechanism of response and in the coöperative action of their various internal parts.

The older school of naturalists laid too much emphasis on the external environment of the completed individual, and of necessity ignored its complex inner mechanism of response to the outer world, because that mechanism was inaccessible to them. The more modern school of genetics lays too much stress on the beginning of individual life, on the assumption, expressed or implied, that at the beginning of things, the solution of vital problems is simpler and easier, and that their solution carries the solution of end results with them.

This is only a fraction of the truth. The beginning of life is apparently simpler than the end because fewer questions are asked. The later structures have not at that time arisen and do not then call for explanation. But no formula for Alpha will serve for Omega. Every phase and stage of life brings its own problems; each one has its own creative power. The biologist must consider each of these problems as they arise, individually and organically; both as independent units and as dependent members of a genetic series, or organic whole. For each phase of life is created by that which precedes, and is the creator of that which follows. For this reason, while every science is tributary to every other science, each one is the rightful arbiter in its own field. The sociologist, who now leans too heavily on the biologist, is as likely to be led astray as those who formerly learned too heavily on the theologian. The true sociologist, like the morphologist, is master in his own field, and in things sociological it is his business to teach the biologist and the theologian. For he alone is best able to estimate the creative value of the coöperative innovations upon which each stage of social progress stands, just as the morphologist can best estimate the creative value and directive influence of perforate gill clefts, and the four-chambered heart, or a particular mode of dentition, without reference to germ-plasma and chromosomes, and without waiting for the students of heredity to decide for him whether acquired characters are inherited, or not. The morphologist knows that the tongue, the hand, the brain, the skeleton, and the yolk of the egg have a directive and creative value that is wholly their own product, a value which can never be measured in terms of chromosomes, or in terms of any other remote antecedent conditions, any more than the properties of water, or protoplasm, or consciousness, can be measured, or be profitably discussed, in terms of chemical elements. Each part and organ, at each stage of its progress, must be measured in terms of its own existing properties, not in those of its constituents, nor in those of remote antecedent conditions.

II.

That coöperation is an important agent in human and in animal societies has often been recognized, but, so far as the author is aware, it has always been considered as something unusual or exceptional in nature, and has been chiefly or solely attributed to the instinctive or intelligent actions of social organisms.

We maintain, however, that coöperation is a universal creative and preservative agent. Its sphere of activity includes cosmic, as well as organic, social and mental processes; its directive influence is as commanding in the one field as in the other, and its creative and preservative power is no less effective whether it is called into action by "trial and error," or by "accident," or by "design."

The broader interpretation herein proposed provides a rational basis for the identification of the two great protagonists in nature: construction and destruction; it helps us to visualize the evolution of world power through the conversion of disorder into order; and it provides a common starting point, a common agency, and a common terminology for all students whose subject matter is the product of evolution, or growth.

The familiar terms "evolution," the "struggle for existence" and the "survival of the fittest" are essentially meaningless and unsatisfying terms because they fail to indicate what is good and what is evil, or to give any comprehensive explanation of how things come into being, why they endure, and how they increase in power. These questions lie at the root of all organic or inorganic products; they are the fundamental questions which all sciences and all religions seek to answer.

But when we realize that evolution is the summation of power through coöperation, that what we call "evil" is that which prevents or destroys coöperation, and "good" is that which perpetuates or improves coöperation; when we realize that the "struggle for existence" is a struggle to find better ways and means of coöperation, and the "fittest" is the one that coöperates best—we shall then realize that science and religion and government stand on common ground and have a common purpose. Until this basic truth is recognized there can be no common goal for intellectual endeavor; no common rules for individual and social conduct; no common standard of what is right and what is wrong; and no common knowledge of that which creates and preserves and that which destroys.

That all evolution, or growth, is the summation of power through coöperative action is axiomatic. But while this axiom does not define what power is, nor what the nature of the ultimate act of coöperation is, it goes far toward satisfying our intellectual demand for some universal instrument of creation and preservation, and at the same time it provides us with a single standard for the measure of service. For service is always the product of coöperative action; it is that which creates and preserves new products by new ways and means of coöperation.

But the extent to which coöperation is attained depends on the extent to which "righteousness" is attained; for coöperation cannot take place except the right things are brought into a definite time and space relation to one another. The chief service of coöperative action, therefore, consists in the conveyance of the right kinds of power to the right times and places for further coöperative action.

The universal measure of progress, therefore, is the progress of coöperative action by the part and the whole for the part and the whole.

In the world at large, progress is measured: (1) by the diversity of its products; (2) by the power of these products to sustain one another through mutually profitable exchange; and (3) by their power to create, with the profits, a better system of coöperative service.

In the organic world, the individual plant, or animal, is created and preserved: (1) by its internal system of organic coöperation; (2) by its coöperative response to the larger cosmic processes in which it resides; and (3) by its coöperation, directly or indirectly, with other living organisms.

And the welfare and security of the entire fabric of organic life, and of its highest products, is assured by conserving the welfare and security of all its coöperating parts.

III.

But every analysis of nature leads to the question of growth, for growth is everywhere an underlying phenomenon in evolution. While the basic impetus to growth is doubtless unknowable, the conditions which divert, restrict, or liberate that impetus may be observed and estimated.

Our interpretation of nature is based largely on the following conclusions concerning growth, which are herewith submitted, without, for the present, further discussion or defense.

1. Morphology is the science of form, and form is the outward expression of growth.

2. The vis a tergo in life is the product of internal coöperative exchange (metabolism).

3. Growth is profitable exchange with the outside world, or the local accumulation of those agents whose demands are the impetus to exchange.

4. The rate at which growth proceeds depends: (*a*) on the inherent nature of the growing point, or its affinity or "demand" for more materials; (*b*) on the distribution of supplies; (*c*) on the capacity of the conveyers, that is, on their capacity to convey commodities to and from the growing points, or the growing points to the sources of supply; and (*d*) on the coöperative, or creative, value of the service rendered by the exchange.

5. A local population of molecules, cells, or human beings, cannot give or take more than the existing conveyers can carry; nor can exchange take place beyond the point where delivery and removal can be made.

6. The capacity of a conveyer depends on the load it can carry, the distance it can be carried, and the speed. The factors, load, distance, and speed, vary with the commodity; and different methods of conveyance are required for different commodities. In human society, there is one method for the individual man, one for water, coal, groceries, and ideas. In protoplasm, different methods are required to convey solid and liquid foods, oxygen, and waste products, or to transmit light and other stimuli.

7. In all such cases, the capacity of the conveyers is limited. It

is temporarily limited by the methods of constructing, or arranging, the conveyers; these methods may be changed or improved. It is permanently limited by the inherent nature of the conveyer, and by the nature of the things to be conveyed; these conditions cannot be modified or improved.

8. But there are no limits to the demands for more materials, for the old demands remain till satisfied, and being satisfied, create new demands.

9. When many commodities are required at a given point at the same time, the rate of growth is determined by the maximum capacity of the slowest conveyer.

10. Since there are unlike local rates and directions of conveyance, unlike local growths arise, unlike in volume, or in quality, or in both. These products of growth become the new agents by whose coöperative action further growth is made possible.

Evolution, therefore, is not due to the subdivision of labor between like units; rather is it that growth inevitably creates different kinds of laborers thereby making the subdivision of labor the imperative condition of their existence.

Growth, therefore, creates the power which is used to satisfy its own demands, and a surplus power, or profit, for freedom of action, which is then used to experiment and explore, thereby finding better ways and means of satisfying its demands.

The same principle may be expressed in commercial or economic terms instead of dynamic terms: progress cannot take place unless the creative value of the service performed pays the cost of the service and yields a surplus profit for freedom. Freedom then becomes the instrument for the discovery, or invention, of better ways and means of service.

11. Growth inevitably creates diversified conditions which tend to check its own progress till released by better coöperation. For growth reduces the immediately available supplies, thereby requiring greater expenditures to procure them; moreover the new internal conditions created by growth create new products, with new demands, faster than the right ways of administering them can be found.

In order, with diminishing supplies, to meet the increasing demands of a growing body, the conveyers must ultimately be utilized to their full capacity; when that point is approached, the rate of growth will diminish, for the expenditures for conveyance will tend to exceed the creative value of the products. The previous rate of growth can then only be maintained by economizing, or improving, or by extending, the ways and means of conveyance. That is to say, either the lines of conveyance must be lengthened, or the rate of conveyance accelerated, or the powers of penetration increased.

But better conveyance simply means better methods of coöperation to that end between the older products of growth; that is, it means the using of those methods which yield more profitable exchange, or which create still more voluminous and diversified products. These new products then constitute the new means to a still larger end; for the creation of diversified products is essential to the invention of new methods of organic coöperation.

12. Growth, therefore, is automatically controlled. For since the rate and the extent of growth depends on the capacity of its conveyers, growth will be checked whenever the new demands created by growth approach the full capacity of its conveyers, and it will be released when better ways and means of conveyance have been found. Thus growth always tends to outrun coöperation, and better coöperation always produces more growth, with new inperfections which still better coöperation alone can remedy.

13. The rate and direction of evolution varies greatly from time to time, according to the methods of coöperation utilized.

These changes of pace and direction in evolution are the real basis of our systems of classifying the organic and inorganic products of nature.

14. The principal kinds of conveyance in the internal organic life of the individual are nervous, alimentary, vascular, and excretory; in the external life they are cosmic circulation, locomotion, and communication. All the epoch-making events in organic evolution are due to the introduction of better service in one or more of these methods of conveyance.

15. The changes of pace in organic evolution, following the adoption of important improvements in coöperation, in retrospect appear as gaps of larger or smaller magnitude, between classes, orders, and

species. These apparent gaps would still be present, even though the records were complete.

16. Growth follows the easiest and most profitable lines of conveyance, and its products accumulate along the lines of least resistance. Thus the form and structure, or morphology, of a given organism is the physical machinery of life and the outward expression of its internal methods of coöperative action. Life (physiology) is the act of creating that machinery.

The rapid rate, the certainty, and the precision of embryonic growth reveal the efficiency of the initial, established methods of organic coöperation. The universal onset of individual senility and death—the one the accumulation, the other the culmination of uncoördinated growth—reveals the present imperfections in the methods of organic coöperation. But the perpetual renewal and reinforcement of individual life, to which evolution testifies, reveal the larger process, and are an assurance of the immortality and perpetual progress of organized nature.

17. Coöperation in the inner life of the individual is a prerequisite to coöperation in the outer life. It is the means by which it attains greater power and that larger physical volume that inevitably goes with larger power; and this larger organic power of the individual is the instrument by which it finds the larger sources of supplies, and the better ways of cosmic and social coöperation; it is the instrument by which it attains that which is good for itself, and avoids that which is evil.

And the demands of its larger volume is an added obligation for better internal and external coöperation in self-preservation.

18. The same laws which prevail in the inner and outer life of animals and plants prevail in the social life of man. Man's social progress is measured by the degree to which he has extended the mutually profitable give and take of coöperative action beyond himself, into the family, tribe, and state, and into the world of life at large. The chief agents of civilization—language, commerce, science, literature, art, and religion—are the larger and more enduring instruments of conveyance which better enable the part and the whole to avoid that which is evil and to find that which is good, and which yield a larger surplus for freedom.

IV.

Let us consider a few special cases that may serve to make our meaning clearer. We shall have space to refer to a few of the more important points only.

Let us assume that equal units or cells are growing under uniform conditions, suspended in a medium from which they draw their varied supplies. Such units will tend to form a solid sphere, increasing in volume till its radius is nearly equal in length to the longest line of conveyance requisite for metabolism (Fig. 1, *A*). The sphere might enlarge beyond that point, but if it did, an ever larger central space would be formed, filled with fluid, or non-living materials and the thickness of its living walls could not be greater than the longest line of effective conveyance through protoplasm, nor less than the one necessary for structural stability, or cohesion.

Growth in a spherical form beyond either of these limits, would be impossible. But since there are more such lines of exchange, in a cylinder or disc, with two or three unlike axes, than in a sphere of equal volume, as fast as all of the possible lines of conveyance are occupied, the spherical body, of necessity, assumes a more and more discoidal or cylindrical form, *C, E*. This change of form cannot be regarded as an extraneous "variation" to accommodate growth; it is the inevitable result of growth attaining its fullest expression. It marks the successive steps in the attainment of the maximum length of the lines of conveyance, the attainment of the maximum number of such lines, and the accumulation of the products of growth along the lines of least resistance.

When the cylindrical, or discoidal, body has reached its limits of growth, still further increase would be possible by opening up the interior, *D*. But here again the increased dimensions attainable by this improvement in conveyance are limited, for the walls could not exceed a definite thickness without the formation of a new barren area (cœlomic cavity) between the inner and outer surface of the walls, and when that limit was reached, growth should again cease.

But the inevitable effects of these changes, even if we assume that no minor complications arose, would be very great. They would tend: (1) to orient the cylindrical, or disc-shaped body to the chief external lines of force acting upon it; (2) to determine its own direction of movement, and thereby determine its distribution in space; (3) to establish definite internal lines of conveyance, unlike

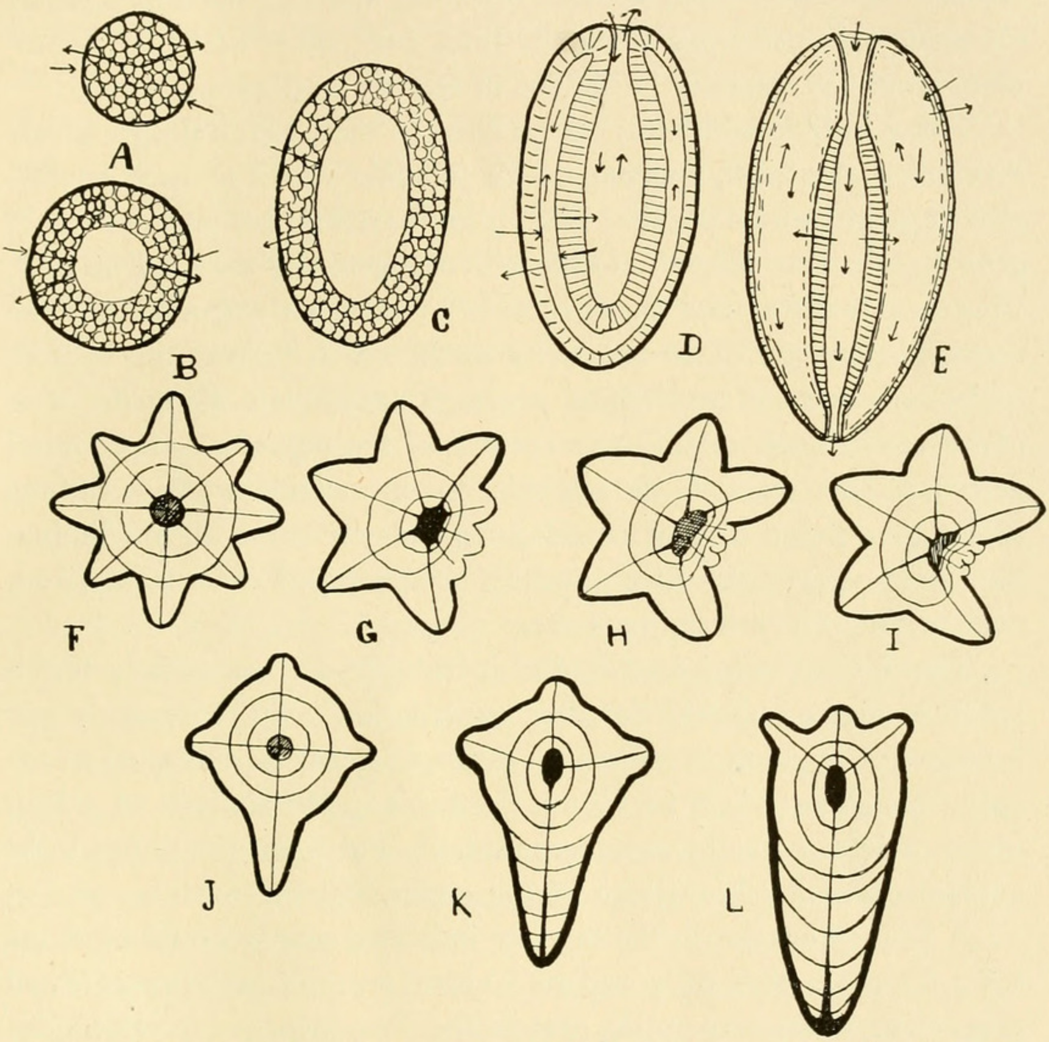


FIG. 1. *A–E.* Diagrams indicating the lines of exchange in a hypothetical growing body suspended in a nutrient fluid, and the form and structure it would assume if growth followed the lines of easiest conveyance and its products accumulated along the lines of least resistance.

F–I. Diagrams to illustrate how local inequalities in radial growth would be obliterated and the original asymmetry restored by the tendency of the other parts to grow along the paths of least resistance.

J–L. Diagrams to illustrate the conversion of radial growth into the apico-bilateral growth, the body of the radiate type, *J,* becoming the head of the bilateral type, *L.* The new cylindrical body supplants the old spherical one owing to the greater economic advantages and creative power of linear and bilateral distribution over radial distribution.

in direction, in content, and in speed; solid bodies passing freely in and out of the interior, and various other agents passing through the walls from within outwards, and still different agents in the opposite directions from without inwards; and (4) the character of the structures produced along the lines and points of unlike conditions would necessarily be unlike in texture and arrangement.

This purely hypothetical case is cited to show that a progressively diversified structure, reacting to the outside world at each successive stage in its own peculiar way, is an inevitable accompaniment of growth, whatever the initial nature of the growing material may be. That is, the form and the structure of such an organism are the resultant products of an internal growth, which follows the lines of easiest conveyance, and whose products accumulate along the lines of least resistance. And the structure of the organism so produced determines its reaction, as a whole, to the outside world. On the coöperative value of that reaction depends its survival, or elimination, or the particular time or place, or sphere, of external environment within which it may endure.

The obvious conclusion is that it is futile, and essentially unscientific in method, to seek for the "explanation" of the structure and function of an adult organism, in terms of germinal units, when the only "explanation" to be found, if any, is in the analysis of a long series of internal and external conditions, and when the things to be explained are the last terms of the series, not the first.

A body produced in the manner indicated above would have the essential characters of a radiate animal, or one growing at equal rates along its corresponding oral radii. Two principal modifications of this method of growth might arise, due to some constant local condition: namely increased tangential growth, or increased growth along one radius. The former, if carried to an extreme, would tend to form a spiral, or might revert to the original radial form (Fig. 1, *F–I*). Such a method of growth carries with it obvious mechanical difficulties and no apparent advantages. The uniradial method, if carried to an extreme, leads toward the bilateral type of apical growth, and carries with it those great mechanical and economic advantages which have led to its retention and elaboration in all the more highly organized animals (Fig. 1, *J–L*).

But none of the higher animals begins its life as an isolated point within a nutrient solution. It is true that an adult animal may be sessile or free, and the mode of life adopted has an important moulding influence on its form and action. But what is more important, because more constant and universal, is the fact that practically every individual metazoan, from the very outset, begins its life as a sessile organism, for it is attached to a more or less inert spherical body (the egg yolk), whose store of non-living contents tends to increase in volume with the progress of evolution. The growth of the embryo is initiated at some point in that body, usually near its surface. Under these conditions, the products of growth inevitably tend to take on the form of a four-layered film, growing in an apico-bilateral direction, with a distributing space, or cœlom, between the layers, because that way provides the most economic solution of the initial problems of exchange upon which growth depends, and the most accessible places for the accumulation of the products of growth; moreover it is the only way in which the more voluminous specialized growth of the higher organisms can take place.

The volume of the egg, or its circumference, at once determines the distance the film has to grow in order to enclose the yolk, and the volume determines the amount of growth that may occur before taking in new food supplies from without. But the volume of the egg food cannot change the graded sequence of time and space conditions that must inevitably appear in a film growing over the surface of a nutritive sphere.

These graded series of time and space relations determine the basic lines of conveyance and growth, which in turn are expressed in terms of structural gradients, or axes and surfaces, such as the gradient to the right and gradient to the left, gradient from head end to tail end, from the neural surface to the hæmal surface, and from the outer layers to the inner layers.

The fact that in all apico-bilateral growth the lines of unlike time and space conditions created by the progress of growth coincide with unlike morphological structures is presumptive evidence that these conditions are essential factors in the creation of those structures and that they are the underlying cause of the homologies in serial organs and concentric layers which prevail throughout the entire series of segmented animals.

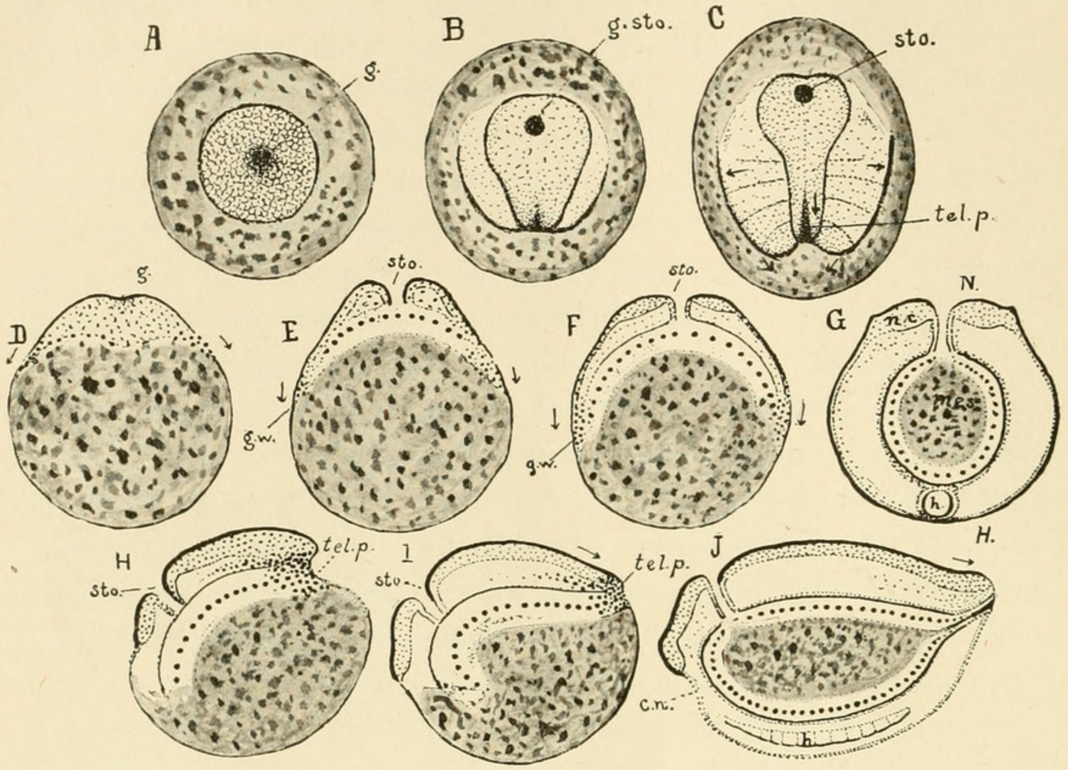


FIG. 2. Diagram to illustrate the transition from the radial to the apico-lateral type of growth, in an arachnid embryo growing on a spherical yolk surface.

A–C. Surface view showing relation of the gastrula stage (radial type) to the apico-bilateral type; also the relation of marginal growth (concrescence), apical growth, blastopore, primitive mouth, and telopore, to one another.

D–G. Same, in transverse section.

H–J. Longitudinal sections showing the four primary channels of exchange, nervous system, alimentary canal, heart, and coelom.

With the growth of the film around the egg, the great landmarks in the morphology of segmented animals may be definitely located: namely, head and tail end, right and left sides, and neural and hæmal surfaces; and the three great channels of conveyance: nerve cord, alimentary canal, and heart, with the segmented channels arising from them, are definitely established (Fig. 2). It might well be said that these landmarks are as unmistakable as the north and the south pole, or the right and left hand, if it were not for the fact that they are persistently confused in practically all of our text books, a condition chiefly due to the incubus of an ancient terminology that had its origin before the days of embryology; a terminology based on the position of the animal in locomotion, not on its internal structure and its mode of growth.

The peculiar advantages of bilateral apical growth over the radial plan, are apparent when we examine the embryo of one of the higher invertebrates, such as a scorpion, or *Limulus,* where all the important organs are clearly laid down in triaxial gradients coincident with the chief lines of conveyance (Fig. 3).

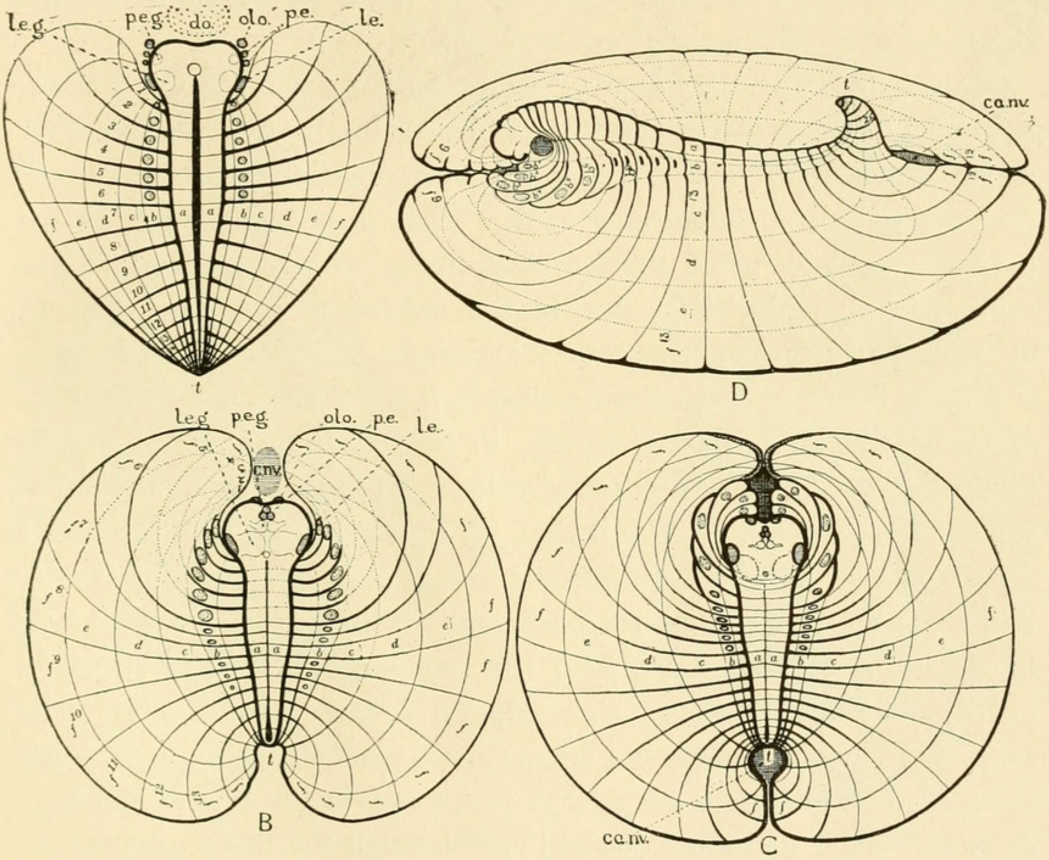


FIG. 3. Diagrams (mercator projections) of arachnid embryos showing how apico-bilateral growth on a spherical surface follows the lines of easiest conveyance and least resistance, thereby determining the chief morphological features of the embryo. From Patten, "The Evolution of the Vertebrates and their Kin."

In the radial plan, there are only two unlike sides, oral and aboral, while innumerable homologous points on corresponding radii, in their time and space relations to the whole, are alike. In the apico-bilateral plan, there are six unlike sides, and no two points in the whole body are exactly alike.

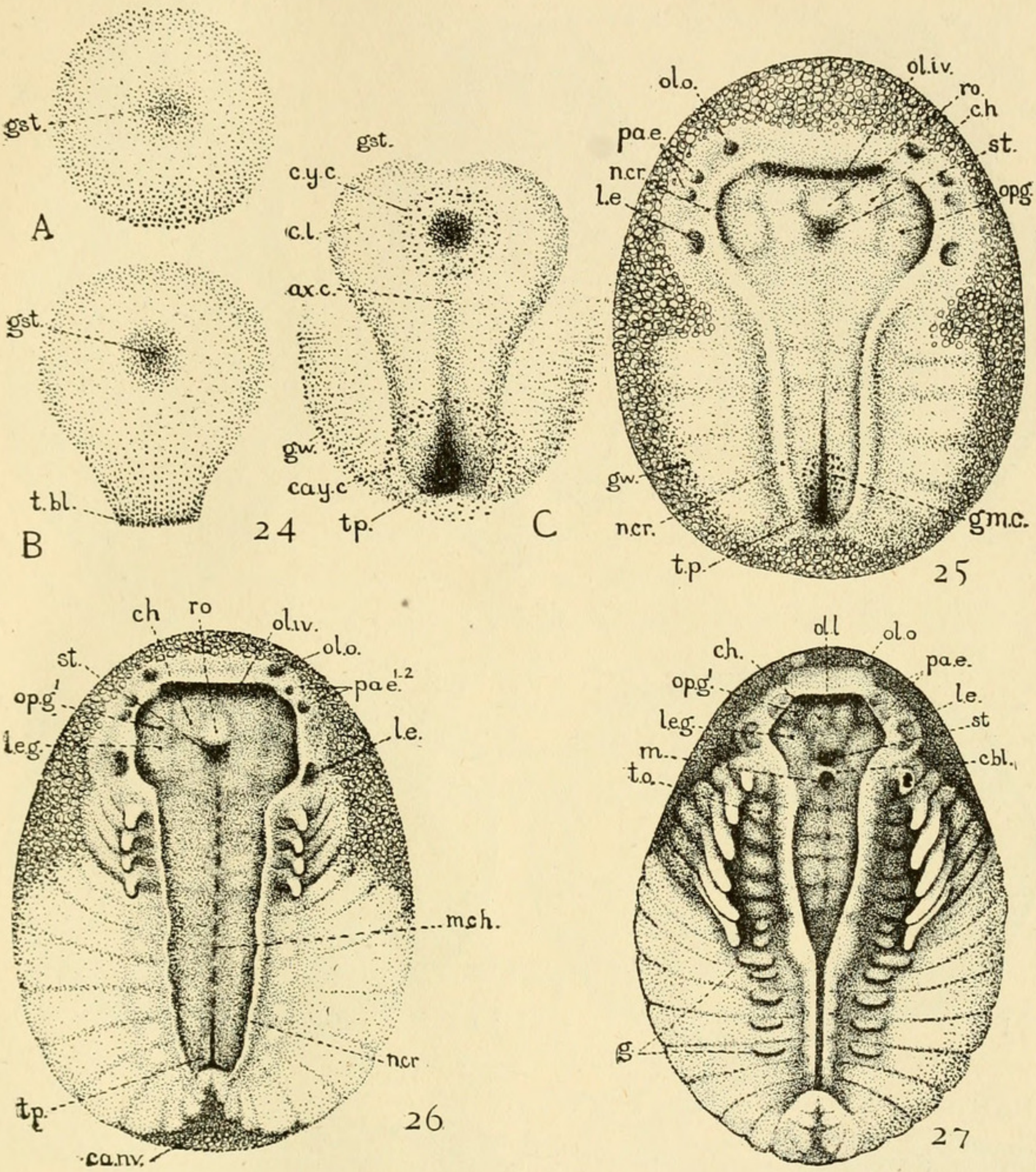
It is this greater diversity in local conditions, capable of infinite expansion, that ultimately creates in the higher, segmented animals the greater diversity in organic products so essential to coöperation and the subdivision of labor.

At the same time it will be observed that the location of the various organs fixes the location of the points of intake and discharge of special commodities thereby establishing a certain necessary order, or sequence of events, in the passage of these commodities through the three great channels of conveyance.

But a linear arrangement of many similar organs, so characteristic of primitive metamerism, would not, in the more voluminous stages of the higher animals, give fullest expression to the latent possibilities of apical, bilateral growth. That is brought about by the gradual breakdown of metamerism, most clearly marked at the cephalic end, and chiefly due to the reduction in the number of multiple parts and to the concentration of functions according to a definite linear order at those points best fitted for the performance of their function. That is to say, in the rearrangement of organs that inevitably follows increase in volume, or in the "competition" of organs for position, each function, as in a growing, well-organized factory, tends to become established in that place in the system where it thrives best, or coöperates best, and for that reason is best able to perform its function. And this tendency will be perpetually operative because of the greater coöperative and creative value of its service to the whole organism when it is so placed. But any arrangement of functions must be subject to the previously established fundamental order of inflow and outflow through the three great channels of exchange: nervous, alimentary, and vascular; to the mechanical requirements of organic and bodily movements; to the inherent limitations in the tensile strength of protoplasm; and to its powers of resonant response.

The history of the evolution of the arthropod-vertebrate stock, covering a period of many millions of years, is chiefly the history of the growth of old organs, the addition of new ones, and the per-

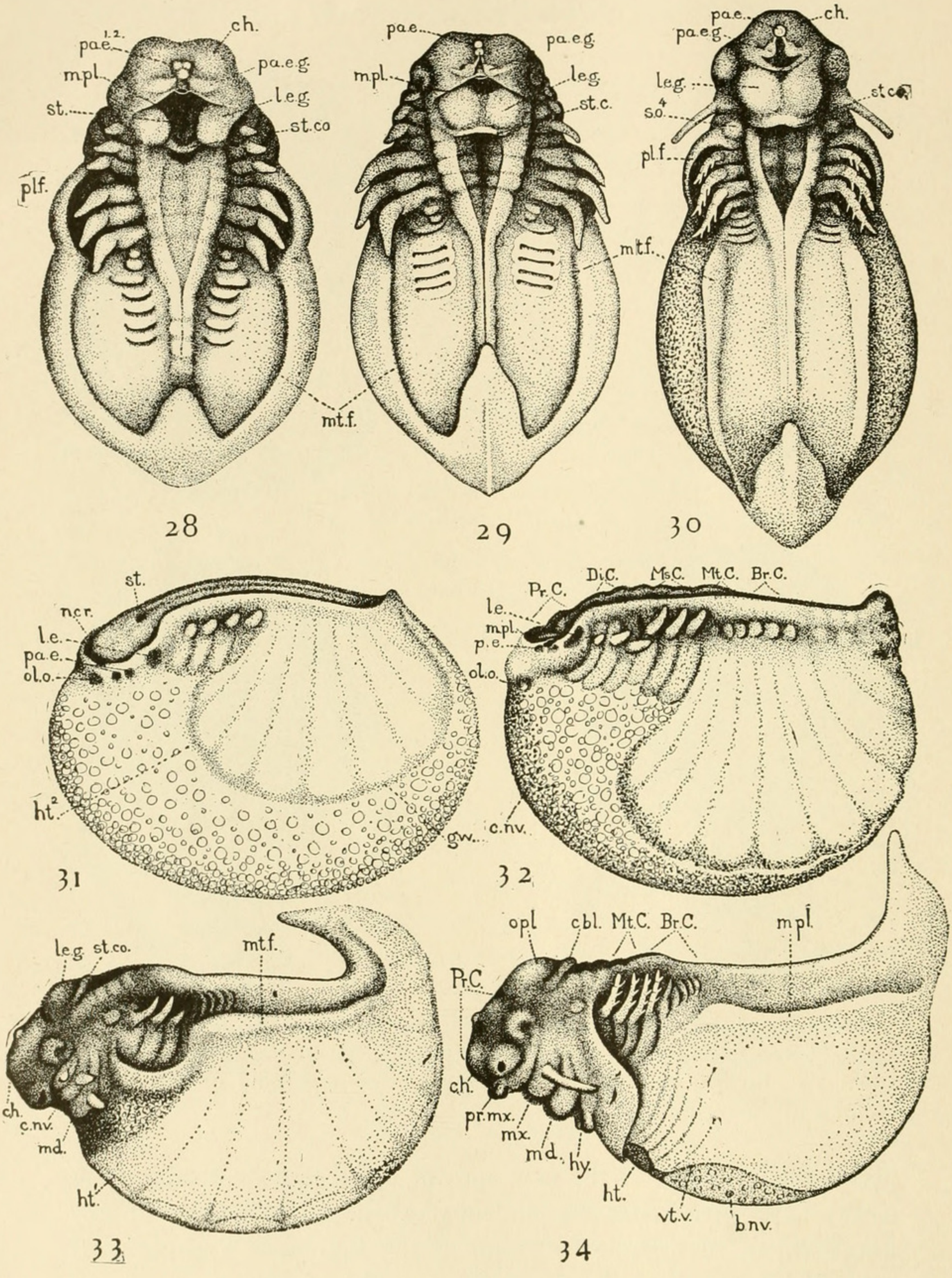
FIG. 4a



FIGS. 4a and 4b. Diagrams illustrating the embryonic development of an arachnid embryo and the hypothetical transition stages to one of the vertebrate type. For further exlanation, see Patten, "The Evolution of the Vertebrates and their Kin."

petual readjustment of the new and the old to one another in such a way as to give better organic coöperation. And because of this improvement in organic coöperation, the individual organism inevitably increases in volume, in power, and in freedom.

FIG. 4b.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If we compare the embryo of an arachnid, scorpion, or *Limulus,* with that of a primitive vertebrate, the basic similarity in their mode of growth, the arrangement of their parts, and the natural transition of one type into the other, is clearly apparent (Figs. 4a and 4b).

In both cases, there are in their appropriate places, the medullary plate, the chief sense organs, the neuromeres, somites, lateral plates, heart, primitive streak, notochord, and germ cells; there is also the inevitable concrescence of the germ-wall as it spreads in an apico-bilateral direction over the spherical surface of the egg, as well as many other more detailed resemblances that we can not go into here.

All these structural resemblances show that the chief points of intake and discharge, the basic routes for the conveyance of commodities, and the sequence of way stations and terminals, that are so characteristic of the vertebrate stock, are already well established in the higher members of the arachnid stock.

But there are some striking differences which we will briefly consider, as they also illustrate the principles we have in mind. The three most important ones are as follows:

1. In the arachnids, the stomodæum, or œsophagus, passes through the floor of the medullary plate, while in vertebrates it lies in front of it.

2. In arthropods, there are several pairs of jaw-like appendages which are located on the neural surface, and which, in chewing or biting, move alternately in a right and left direction. In typical vertebrates, the jaws consist of one or two unpaired arches, the posterior arch being freely movable in an antero-posterior direction.

3. The gill chambers of the vertebrates open into the alimentary canal, while, in arachnids, they do not.

In at least two of these cases, the differences are more apparent than real, for the prevailing methods of growth in the arachnids, if carried further, would ultimately lead to the conditions found in the vertebrates.

That is to say, the concentration of the cephalic neuromeres in the head region of the arachnids has already narrowed the stomodæal opening through the floor of the forebrain to a minute canal barely large enough for the passage of fluids, thereby compelling the great majority of arachnids to adopt a liquid diet.

Moreover the arachnid medullary plate, by a process of embryonic invagination and overgrowth, barely falls short of forming a closed chamber. Neither of these processes could be carried much further without either completely constricting the œsophagus, or shutting up the mouth inside a hollow brain. Such an event would be fatal

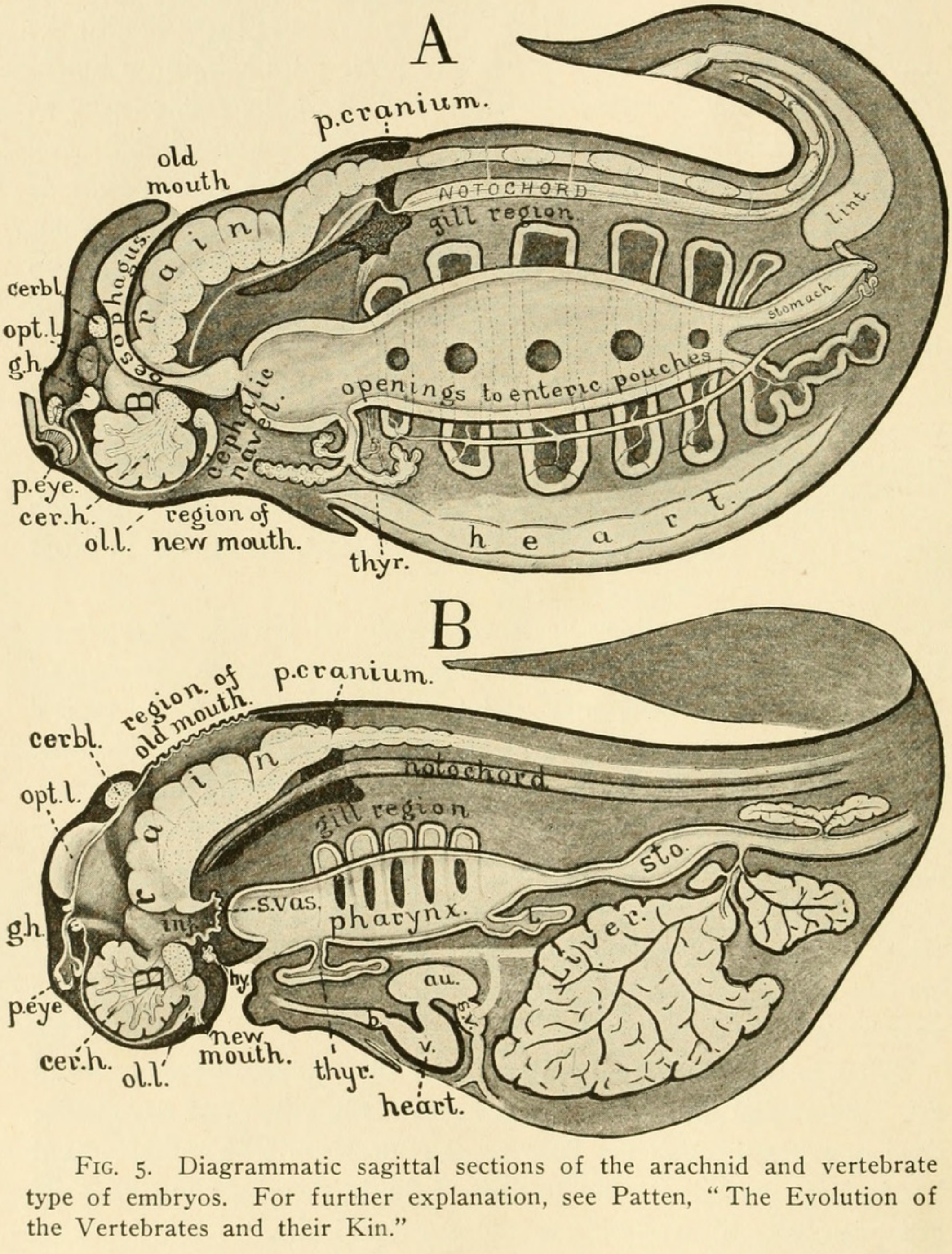

FIG. 5. Diagrammatic sagittal sections of the arachnid and vertebrate type of embryos. For further explanation, see Patten, "The Evolution of the Vertebrates and their Kin."

unless a new opening into the alimentary canal were already available elsewhere. Such an opening is available in what I have called the cephalic navel, a temporary embryonic opening into the enteron, lying on the hæmal surface of the embryo in a region corresponding to that where the vertebrate mouth is located.

What has probably taken place, then, is this: in the vertebrates the old invertebrate œsophagus (Fig. 5, *A*) has been gradually choked up by a vigorously growing nervous system and its external opening competely enclosed within the brain chamber. A new entrance to the alimentary canal was then established through an old channel, of unknown significance, in a more convenient place. The remnants of this old, shut-in mouth and œsophagus are still conspicuous features (otherwise inexplicable) in the brain of all vertebrates, *i. e.*, the infundibulum, the saccus vasculosus, and the large opening in the roof of the fourth ventricle, now closed by a thin membrane, the choroid plexus (Fig. 5, *B*).

The position of the jaws is also changed by the same cause, for the great size of the embryonic forebrain, at an early period, lifts the head of the embryo off the surface of the egg, and forces the jaws, or oral arches, apart, toward the hæmal surface, where they converge around the new oral opening (Fig. 4, 31–34). At least three pairs of arches are involved in this movement, and the important steps in the process may still be observed in many vertebrates.

The transfer of all three pairs of oral arches to the haemal surface may be readily observed, although heretofore overlooked, in frog embryos (Fig. 6). Their ultimate union, along an elongated median depression, gives rise to the fronto-nasal process, the maxillary and mandiblar arches, and gives us the key to the morphology of the facial region in all the higher vertebrates.

Similar conditions may be seen in the adult stages of a very primitive living vertebrate, Myxine (Fig. 7, *E*), and also in the Ostracoderms, which form the connecting link between the giant sea scorpions and the true fishes. In Bothriolepis (Fig. 7, *A'*) both the maxillary and mandibular arches are provided with bony plates located on the hæmal side of the body and which work against each other in a transverse direction, thus furnishing an instructive transitional stage between the typical arthropod and typical vertebrate jaws.

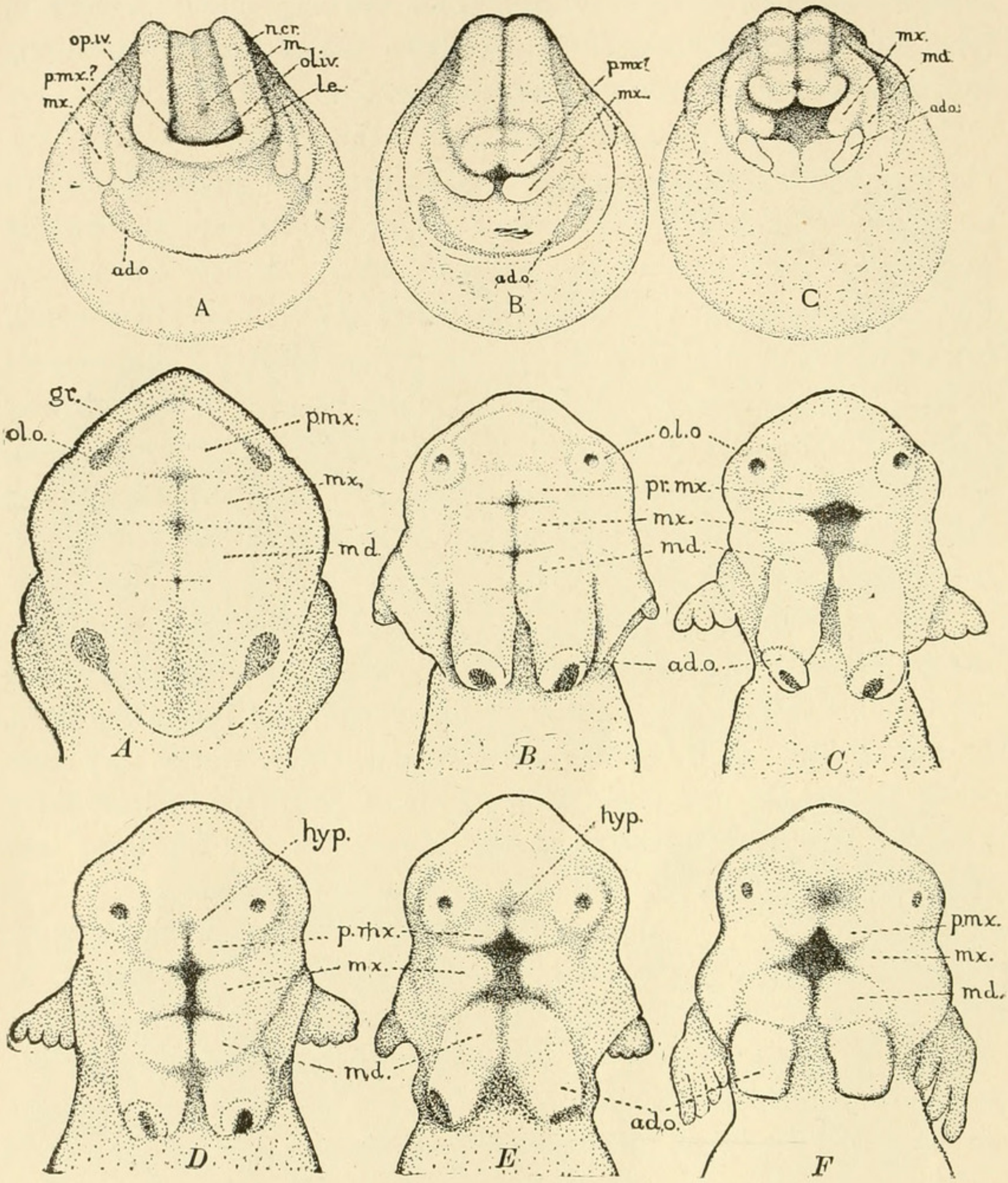

Fig. 6. Development of the jaws of the frog. The figures show the presence of three pairs of appendage-like oral lobes of the arthropod type, their migration from the neural to the hæmal side of the head, and their union to form the transverse unpaired upper and lower jaws of the vertebrate type. From Patten, "The Evolution of the Vertebrates and their Kin."

Evidence of a similar condition is seen in man, for one of the chief events in the embryonic growth of his face is the concrescence of several pairs of oral arches to form the unpaired jaws, and some of the adjacent organs of the adult (Fig. 8).

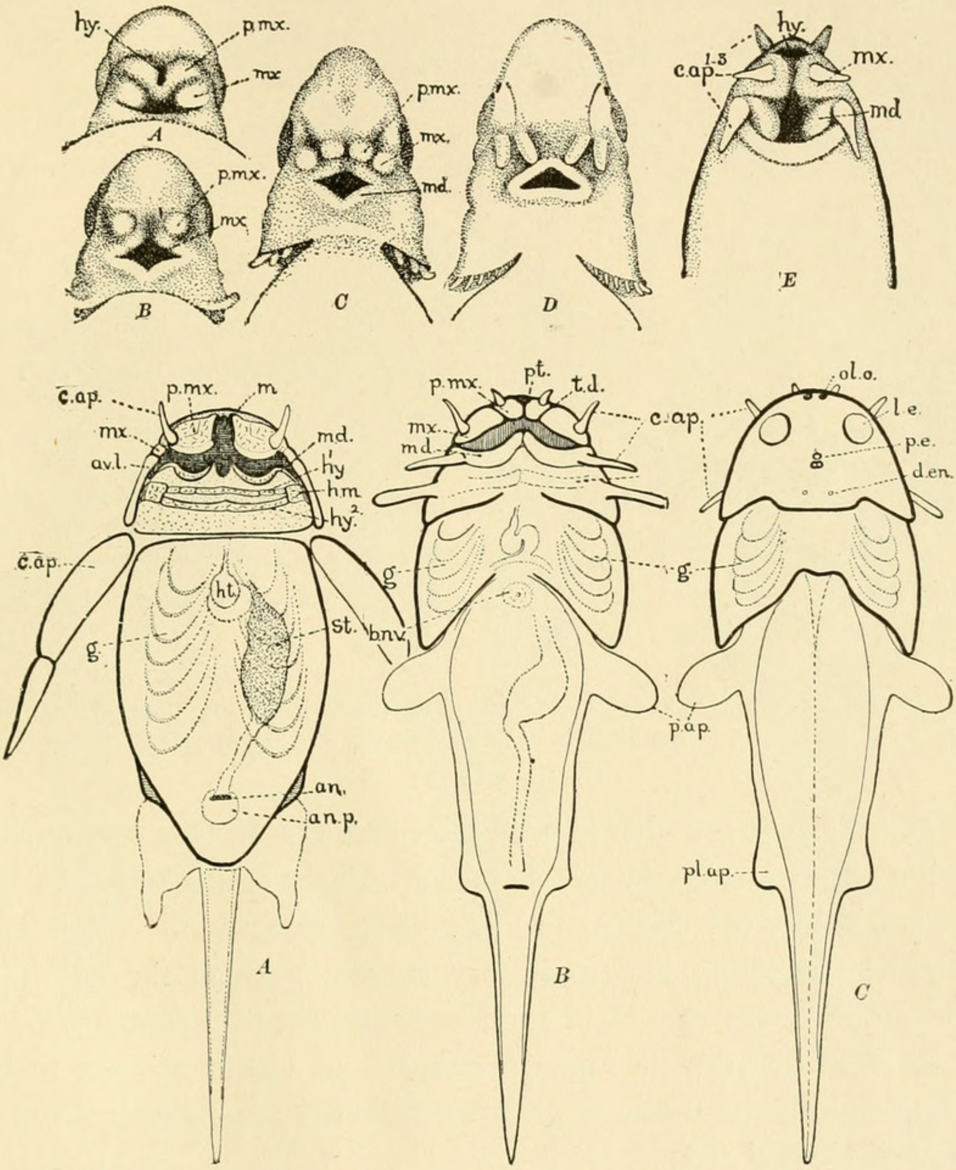

FIG. 7. *A–D.* Development of the jaws of the sturgeon. After Salensky. *E,* head of *Bdellostoma,* a primitive vertebrate, showing three pairs of oral appendages similar to those in the frog embryo. *F, Bothriolepis,* an ancient, extinct animal of vertebrate affinities, with mouth parts intermediate in character between those of arthropods and vertebrates. From Patten, "The Evolution of the Vertebrates and their Kin."

The conditions that led to the opening of the ingrowing gill chambers into the outgrowing enteric diverticula are not apparent.

although such an opening seems to have taken place at several different times in the evolution of the arachnid stock.

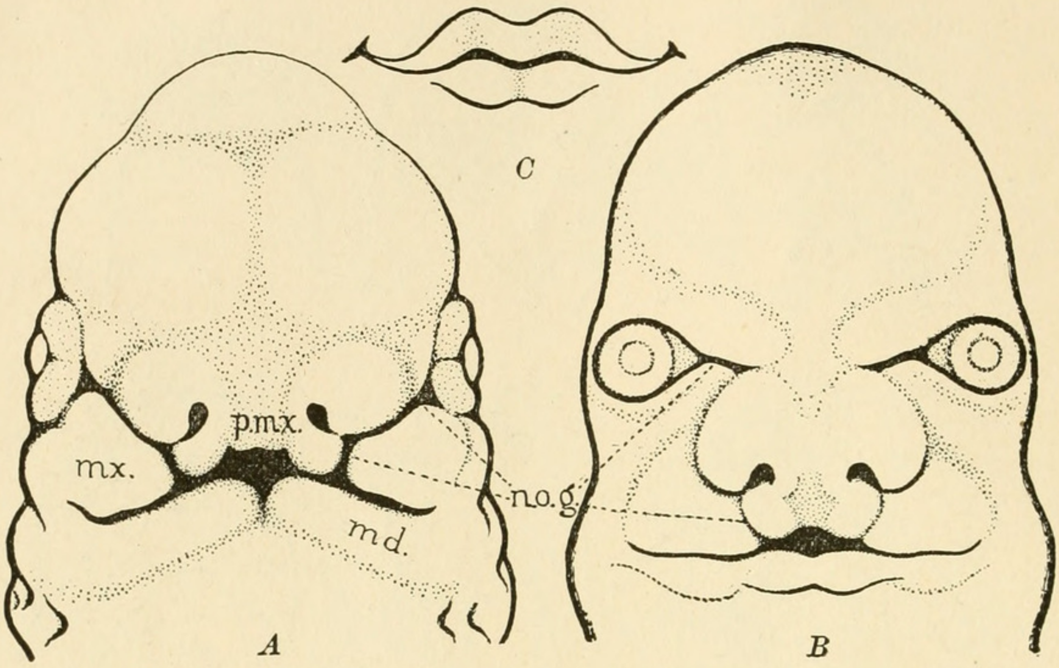

Fig. 8. Human embryos showing the three pairs of oral arches that help to form the face and jaws. From Patten, "A Problem in Evolution."

But the facts we wish to emphasize here are that the communication in vertebrates of the gill chambers with the alimentary canal has two very different effects: (1) it greatly increases the respiratory power by directing the respiratory current through the gills in a constant direction, that is, in at one side and out the other, instead of in and out through the same opening; and (2) it at once makes it impracticable to carry on digestive action at any point in front of an open visceral cleft.

The thyroid gland is doubtless the remnant of the prebranchial digestive glands, modified, or temporarily thrown out of commission, by the opening up, in this manner, of the visceral clefts (Fig. 9).

The corresponding organs of the arachnids (scorpion) are voluminous thoracic, or prebranchial, digestive glands, which in their grosser morphological relations, and in their histological structure, strongly resemble the thyroids of vertebrates.

These differences between the mouth, jaws, and gills of vertebates and those of the arachnids are as significant, therefore, as the resemblances, and point to the same conclusion. For the peculiar conditions found in the vertebrates are seen to be the inevitable result of the conditions prevalent in the arachnids; here, as elsewhere, growth inevitably occupies the easiest paths of conveyance, and the products accumulate along the paths of least resistance.

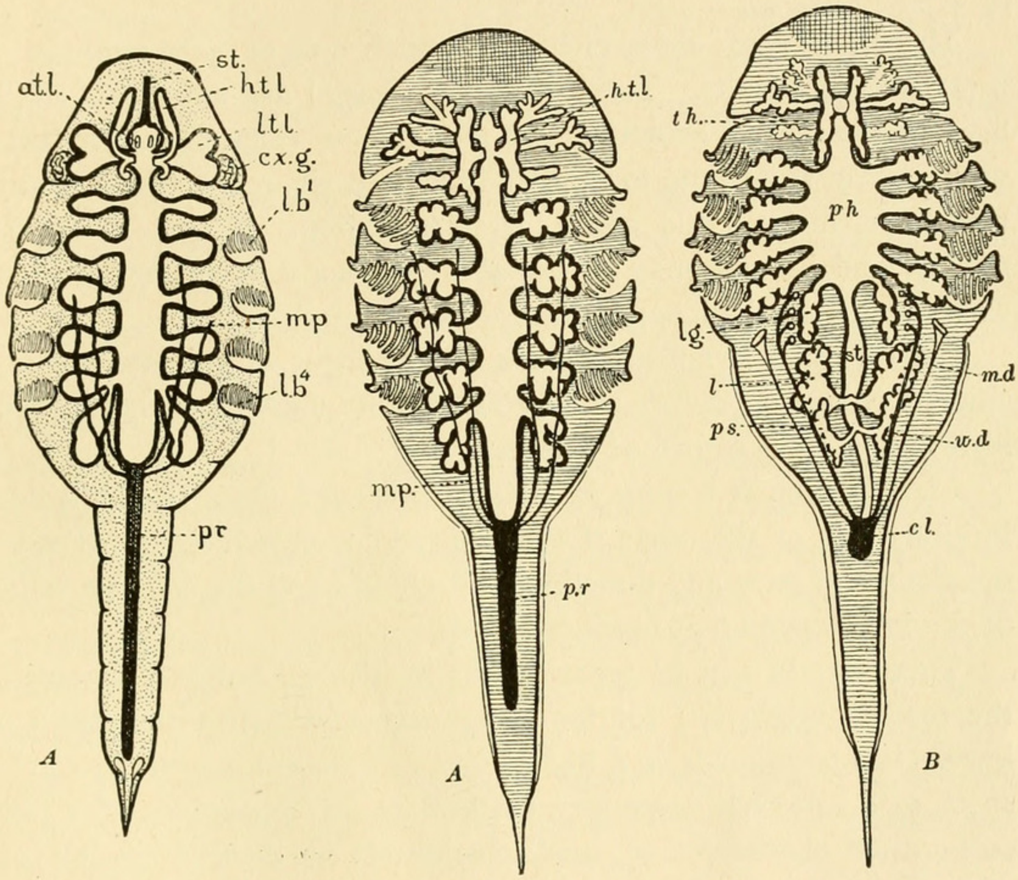

FIG. 9. Diagrams indicating the probable manner in which the arachnid gill sacs, in vertebrates, come to open into the alimentary canal. The usage of these passages for respiration prevents their usage for digestion. The anterior hæmal outgrowths, which never communicate with gill sacs, give rise to the thyroid glands. *A*, scorpion. *B*, hypothetical transition stage. *C*, vertebrate. From Patten, "The Evolution of the Vertebrates and their Kin."

In these particular cases, the forced migration of the jaws to the hæmal surface, the formation of a new mouth outside the medullary plate, and the opening of the gill sacs into the alimentary canal, result in mechanical and economic improvements of the greatest importance. The great coöperative value of these improvements led to the rapid expansion and the readjustment of other organs expressed in the term evolution, and the increased rate with which these events follow one another is perhaps the chief reason for the large gap, in retrospect, between the vertebrates and their more immediate arachnid ancestors.

V.

The special cases above cited are peculiar only in the magnitude of their ensuing results. The principles involved are universal. It is because the rate of evolution and the creative value of its products vary greatly from time to time and place to place, that there is any real basis, historic and vital, for classification. It is this historic process and its sequence of causal conditions that our systems of classification tend to portray more and more fully.

Classification is not merely the arrangement of animate and inanimate things according as they are like or unlike, any more than history is a mere record of events.

Classification is history in tabloid form, and there is little value in either one or the other if they do not in some measure express the change of pace and direction of evolution and the creative value of the innovations that produced them.

There would still be great epochs in history, however complete the records might be; for the same reason, the transition from a lower class of animals to a higher one will always appear, in retrospect, as a relatively large gap, marked by the appearance of a few coöperative characters of small magnitude in themselves, but of great creative value.

A familiar example of this principle is seen in the transition from fishes to amphibia, where the chief event was the apparently insignificant enlargement and short-circuiting of one of the branchial blood vessels. This event ultimately led to the substitution of lungs for gills, and to many other changes of far reaching importance in the internal and external administration of their lives.

The four chambered heart; the hot, even tempered blood; placental nutrition; and articulate speech, are other examples of those incidental products of growth, whose appearance is epoch-making in evolution, because of their extraordinary coöperative value and their power to create new instruments of conveyance, or to reach new sources of power.

VI.

In the administration of the outer life of the individual, the same laws of growth prevail as in the inner life. That is, group growth, or increase, in the number of individuals follows the easiest lines of conveyance (of supplies to individuals, or of individuals to supplies) and the products of growth accumulate, provincially, along the lines of least resistance.

And the individual itself is subject to the same law of coöperation as are its own internal constituents. It cannot endure except in so far as the new problems in the external administration of its life, that are raised by increase in numbers, are solved by the use of better methods of coöperation with other individuals and with the physical conditions outside itself. But the very power essential to that end is the power which is created within the individual by its methods of internal organic coöperation between muscles, and nerves, and other organs. Thus there are five principal methods of coöperation essential to the evolution of life: (1) Cosmic coöperation; (2) internal organic coöperation; (3) external coöperation of the individual with its physical surroundings; (4) external coöperation of individuals with one another (internal social coöperation); and (5) coöperation of groups, or classes, of individuals, such as plants and animals, or different nationalities, with one another (external social coöperation).

VII.

While the chief gain, result, or end in life is the perpetuation and aggrandizement of the individual unit, there are two distinct and mutually supplementary methods, in the long run, of attaining that end, namely: for the individual (1) to take all it can get, and (2) to give all it has; because thereby a larger product is attainable than can be attained by any individual alone, and because the welfare of the individual is better assured through the larger unit of which it is a coöperative part, than it is by its own unaided efforts.

Or, stated in other terms: the greater power of the individual to take what it requires is gained by using more profitable methods of internal organic coöperation. This internal power of the individual is the essential instrument for more effective external, or cosmic and social, coöperation; and it is again reinforced by giving it, or expending it, in coöperation with other individuals, for a still larger unit. The ultimate gain in this dual method of give and take is a progressive summation of organic power at the expense of inorganic and unorganized nature; and this process is progressively creative and preservative.

Thus the ultimate "interests" of the larger and of the smaller unit are identical; and the "interests" of the one and the other are alike served by the freest give and take of coöperative action; for organic evolution, or progress, is nothing else than the summation of power through the coöperative action of its constituents.

The "conflicts" in nature, which have always claimed such a large share of man's attention, are often mistaken for creative and constructive agents. The exaggeration of this tendency in recent years is an error for which the biologists themselves are largely responsible. But the one supreme truth that nature insistently teaches is that conflict and aggression are never creative forces, except in so far as destruction may serve to redistribute power so that ultimately it may be linked with other powers in better coöperative action. Evolution and progress is always measured by construction, or by the degree to which conflict decreases and coöperation increases.

The confusion of thought indicated above arises from the failure to recognize that the struggle for existence, if there is such a struggle, is a struggle to find better methods of coöperation, and the "fittest" is the thing that coöperates best.

In the larger estimate of progress, the progress of coöperative action in the inner and in the outer life of the individual, as well as in that of the great social life of nature as a whole, of which every individual is an organic part, must be given their correct, relative values; for each one of these three phases of progress is an instrument to the same end, the aggrandizement and security of the whole by the part and the part by the whole.

From this larger point of view, what we call "evil" is that which prevents or destroys coöperation, and "good" is that which perpetuates and improves coöperation. Evolution in nature, as a whole, proceeds with the attainment of righteousness, or as fast as the better ways of avoiding that which is evil and of attaining that which is good, are found by the part and by the whole.

As the animal and plant life of the world becomes more complex individually, and more unified as a whole, the necessity for wider and better coöperation in exchange becomes more imperative; or to put it another way, life at large, individually and in its various aggregates, grows in unity and in the summation of power, as fast as it finds and makes use of better methods of conveyance for mutually profitable exchange, or creates new instruments to that end.

In the inorganic world, and in the lower phases of organic life, the right way to coöperative action is found by "chance," during a prolonged period of trial and error. It is a slow process, but inevitably accumulative and accelerative, for there is a directive and preservative element, a tendency towards finality and completion, in coöperative action, that is none the less effective whether it be found by accident or by design. In the higher phases of individual life, the more elaborate series of preservative and coöperative acts are called "instincts and intelligence." The chief element in "intelligence" is the power to foresee and to select the better time and place for coöperative action, thereby greatly accelerating the process of attaining good and avoiding evil.

VIII.

The same laws that govern the growth of plants and of animals, govern the growth of human society. Society in its growth follows the easiest and most accessible lines of conveyance; and its rate of growth depends on the coöperative value of its inventions for the preservation and profitable exchange of its own products, intellectual or physical. Science, literature, and art, are the reservoirs and distributing channels for the one, and commerce for the other.

They are the agents produced by growth that supply the demands of growth, and the profits of this exchange will provide the new means for supplying the new demands.

Need it be said that the chief function of statesmanship is to keep these social reservoirs full and the channels of exchange open; and to find better methods of coöperative action between individuals, states, and empires, in order better to meet the new problems in the give and take of commodities that arise with the growth of the individual and of his various social groups?