to the writer to state that the article in question was written last January, before the final results of Professors Oliver and Scott had reached me, and that the footnotes which called attention to the later discoveries were added in April, when I read the proof.

With regard to the statement in the opening paragraph that the term Cycadofilicales was destined to become a permanent acquisition to taxonomy, I had in mind rather the idea that botanists would henceforward be unable to dispute the existence of paleozoic plants intermediate between the Pteridophyta and the Gymnosperms, rather than the question of terminology, and hence did not notice this slip of expression in a paper which further on mentions a new and vastly more appropriate name for the group in question.

EDWARD W. BERRY.

PASSAIC, N. J.

SPECIAL ARTICLES.

EVOLUTION AND PHYSICS.

EMINENT British biologists have recently visited severe criticisms* upon Lord Kelvin for giving voice to the opinion that evolution lies beyond the borders of physics and chemistry. The zeal with which they have hastened to the defense of current mechanical hypotheses of evolution apparently causes them to forget that it is exactly these physical conceptions with which Lord Kelvin may be supposed to be qualified to deal. And when Lord Kelvin admits that the 'forces,' 'principles,' 'energies' or other abstractions in use among physicists are not adequate for even a formal explanation of such biological phenomena as evolution, he states what is well-nigh axiomatic to some, and reaches a point of view appreciated by rapidly increasing numbers of biologists.†

The idea that there are biological phenomena essentially different from those of physics and chemistry has nothing to do with the theory of 'vital force' of half a century ago. It does not overlook the vast amount of physics and chemistry already found in plants and animals, nor the probability that multitudes of similar facts remain to be discovered. To argue, however, from the progress of knowledge in these directions that all the phenomena of organic existence are to be explained in current physical terms is to imitate the balloonist who reasoned that he would be able to see all the way around the earth if he could only go high enough.

It is entirely possible, of course, to range organic evolution under chemistry or physics, but at present it seems not to assort well with the other phenomena treated in these sciences. The difference appears to be, furthermore, not merely one of degree, but of kind, so that it may well be asked whether it is not more scientific for Lord Kelvin to recognize and admit such a distinction, even though it may prove ultimately to have rested on a present limitation of knowledge, than for his critics to insist on the identity of phenomena between which no indication of relationship has been shown. At least we must expect that the unprejudiced layman will think it quite as possible that the biologists have been indulging in bad physics as that Lord Kelvin is totally in error with regard to the rôle of physical forces in biology. The outsider might even wonder why the eminent specialists from the two branches of knowledge are not organized as a joint committee to consider whether their fundamental conceptions are the same or not, instead of wasting time in mutual recriminations of ignorance. In the scientific world, such charges can not, of course, go amiss, but conscious ignorance is better than unsupported assertion.

Whether the formation of crystals should be called fortuitous or not is another question of words; it will hardly be insisted that it is a completely fortuitous 'concourse of atoms' which makes crystals of regular form from a solution stirred up in a beaker; to cover our ignorance we ascribe to some substances a special property named crystallization. If protoplasm could be obtained from a similar dissolved mixture of its ingredients, this would be ascribed by parity of ignorance and logic to 'plasmatization' or whatever such a prop-

* SCIENCE, N. S., XVIII., 138, July 31, 1903.

† See, for example, 'A Text-book of Botany,' by Strasburger, Schenck, Noll and Schimper, p. 158, London, 1903.

erty might be called. But such a discovery would not end the physico-biological controversy, nor have any serious effect upon it, since we know already that the 'chemical compound' termed protoplasm, however originated, has numerous activities not shared by other compounds, and explainable only by the prediction of numerous thus far unexplained properties, such as assimilation, growth, irritability, reproduction, etc.

The biochemist hopes to make protoplasm in a beaker, but in transforming his homogeneous jelly into a 'sprig of moss' he will need to utilize agencies not only unexplained, but not even analogous to the postulates or properties now ascribed to unorganized matter. These agencies or properties of life are doubtless as 'natural' as those treated in physics and chemistry, but they are different. To call them 'creative' or 'directive' is, perhaps, open to objection, but they are certainly conservative, coordinative and constructive in a manner and degree for which we have no extravital analogy. The directive idea, however, is by no means extinct among biologists. Naegeli's '*Vervolkommungsprincip*' has been succeeded by an equally hypothetical 'mechanism of heredity' which Professor Weismann and his numerous followers are still seeking in germ-cells. It is possible, however, to frame an evolutionary theory without recourse either to 'phyletic vital force' or to incredibly complicated and yet inadequate mechanical determinants.*

It is needless to fear that Lord Kelvin will destroy the fact of organic evolution established by Darwin, but, on the other hand, no amount of argument can rehabilitate Darwin's first theory of the developmental process, that the environment causes variations and then selects the desirable changes. This view was abandoned by Darwin himself, and is now held in its original logical integrity by very few working biologists, the non-inheritance of acquired characters having rendered it untenable. The present multiplicity of theories of development is a sufficient indication that there is, as yet, no generally accepted explanation of evolution or of the other characteristic properties of life, and no 'complete mechanical theory of the universe.' Lord Kelvin will perform an important service for biologists if he encourages them to attempt an adequate formulation of the ascertained facts of their own science instead of thinking it necessary to base their structure on terms and concepts borrowed from widely separate fields of research.

The Vocabulary of Science.—The interest of such a discussion as that precipitated by Lord Kelvin is not confined to the varied opinions advanced; it furnishes also an excellent example of the more general and fundamental fact that the 'advancement of science' depends quite as much upon expression as upon investigation. This is true not merely because it is necessary to frame intelligible statements of scientific results which are to be of practical use, but because investigation itself can not advance far beyond the language in which its results must be interpreted. The rational arrangement or classification of facts is supposed to distinguish the methods and discoveries of science from those of mere accident and empiricism.

As soon as they leave concrete data and distinctions, scientific men fall to dogmatizing like any other theologians, metaphysicians or philosophers. This is not, however, because of any special inconsistency or weakness, but because all are at the mercy of an inadequate vocabulary and can say only what has been said already, or something sufficiently similar to require a new word only now and then. On the borders of knowledge each word does duty for a great variety of ideas, and the same proposition often conceals essential diversity of thought. The less known about a subject the easier to dogmatize, or to formulate and establish a vocabulary, and an established vocabulary is a fact to be reckoned with as much as any other.

Science and general literature are thus forever at war because, while comprehension advances from the concrete and particular to the general, the language in which ideas must be

* 'A Kinetic Theory of Evolution,' SCIENCE, N. S., XIII., 969, June 21, 1901; 'Stages of Vital Motion,' *The Popular Science Monthly*, LXIII., 14, May, 1903.

formulated often develops in the contrary direction, from the abstract to the concrete. Generalizations built of facts are not abstractions, but collective facts, while the words in which they are expressed nearly always trace their origins back to primitive abstractions. 'Force' was originally a mere synonym of 'strength,' but has now become, in the minds of many, a physical entity, and 'heredity' or 'heirship' is actualized into a determining 'principle' of evolution. Philosophy came before science, metaphysics before physics and physics before biology, in the history of progress from the abstract to the concrete. The phenomena of personality are most familiar, but they have received the slightest scientific attention; in the phenomena of life we also participate, but have only begun to generalize, while the phenomena and theories of unorganized matter are formulated almost as extensively as those of metaphysics, and with the assistance of as many abstractions. Recent discussions of the constitution of matter read like metaphysical treatises, lacking only a certain ponderous assumption of certitude. The idealistic physicists argue that matter is electrical, while the materialists suspect that electricity may be material.

Forces and Properties.—In dealing with unorganized matter the physicist has an apparent advantage over the biologist, since he is able to command definite quantities and uniform materials and conditions of experiment, and thus secures results which can be stated in mathematical form, but this has not given him, as yet, an adequate insight into the nature and causal relations of the phenomena with which he deals. It is not the physicists who are attempting to extend their practice into biology, but the biologists who insist on paying tribute to physics, even after such an eminent specialist as Lord Kelvin has pronounced their case hopeless, unless recourse be had to other 'forces' than those at his professional command.

Physicists are willing to recommend 'vital principle' as an aid in biological difficulties because similar 'hypothetical entities' are much used to assist in the formulation of physical facts. That 'vital force' does not really explain anything is no objection to it from the physical standpoint; neither do other 'force' abstractions. Their function is merely to assist the mind to follow ascertained sequences of facts; they are our algebraic substitutes for unknown causal connections. As soon as we thoroughly understand the mechanism, the instinct of causality is satisfied and the hypothetical 'force' becomes superfluous; it is useful only if it assists observation and experiment. The old vital force which 'terribly hampered' biological investigation was a thoroughly bad abstraction, and has been consigned to a merited oblivion. The unwillingness of biologists to restore this idol or to set up another in its place should not, however, lead them to ascribe any superior virtue to the gods of the physicists, unequally doomed to dethronement.

Physicians have long since given over general theories of disease and are reconciled to treating symptoms and removing causes. When other branches of science have received a similar amount of study they may be content with phenomena and leave the 'entities' to the metaphysicians. Phenomena, instead of being assigned to unknown entities, are more conveniently and practically classified into groups called properties, and in biology we are ready to give up the notion that each property or group of phenomena must have a 'force' or other hypothetical entity behind it. The perception has come that the properties of life are not distinct 'forces,' but are merely different aspects of the same vital process. It is as a process rather than as a 'force' that life appears to lie beyond the phenomena of physics.

It did not improve matters to analyze evolution into two hypothetical opposing 'forces,' heredity and variation, or heredity and environment; these abstractions have long concealed the universal facts that organisms follow each other in series of similar but not identical individuals, and that species are not merely influenced by environment, but are normally in motion. There is no heredity which keeps organisms exactly alike, nor any

environment in which they will remain so.* The chief effect of these abstractions is to breed others as hypothetical as themselves. The facts are very simple, the abstractions become vastly complicated. Biologists are zealous for mechanical theories of their own making, but when Lord Kelvin fails to recognize these as adequate from the physical point of view and offers a 'vital principle' instead, the gift is rejected without thanks, and with the ungracious reply that it is a cast-off notion which ceased to be useful many years ago.

If evolution is ever explained in physical terms it will probably be done by making generous additions to the recognized properties of matter, a course to which physicists are certainly nothing loth, but they are duly warned by Professor Lankester that such 'facile and sterile hypotheses' will not satisfy biologists. Indeed, it may be that the failure to recognize a distinct category of vital phenomena lies not so much in what might be called a materialization of life as in a certain vitalization of matter. We predicate for matter our own mechanical limitations and refuse to consider such a possibility as the interaction or mutual sensitiveness of matter through space, although the alternative theories of ethereal media are extremely complicated and contradictory.

Comprehension versus Formulation.—Physics is considered fundamental to biology because organisms are made of matter, but biology is in advance of physics in the apprehension of its phenomena, and we are as likely to learn physics from biology as biology from physics. Life is, as it were, superposed on matter, and personality on life; each must have the qualities which make the next stage possible, but each stage may be viewed also on a plane of its own, and our intimate acquaintance with phenomena has not gone up from the bottom of the pyramid, but from the top down. The ultimate facts of matter appear fundamental from the mechanical standpoint, but the fabric of knowledge has been constructed thus far without them, and science must continue to advance laboriously from the known to the unknown. It may be illogical to discover the basal facts last, but such is the indication of history, to which it is well to be reconciled.

Every-day objects and incidents are the last to secure critical study and scientific elucidation; it is the obscure and incomprehensible which challenges our curiosity. Primitive man seems to have taken interest first in dreams and specters. Astronomy, as incidental to astrology, was the earliest of the physical sciences, and still owes much of its popularity to the instinctive attraction of mystery and awe. With mental habits and instincts formed by such a history it is not strange that thought still travels unwillingly from the remote and abstract to the concrete and adjacent, and that even in science we are continually tempted to value formulation above concrete perception, and to confuse abstraction with generalization. The cabala is discarded and the syllogism is distrusted; in time it will become apparent that even the mathematical equation yields only the amount of comprehension originally put into it, and has no virtue beyond any other method of accurate statement. The 'complete mechanical theory of the universe' is not yet, nor is its completion to be hastened by eking out the hewn stones of ascertained fact with blocks of the dried mud of abstraction. Such material may be very useful in temporary shelters for the workmen, but it has no place in the permanent structure.

A General Classification of Phenomena.—Although abstractions and 'hypothetical entities' must be excluded from among the results of scientific study, there is still great need of general terms as a means of arranging ideas and classifying facts. It is here that biology may possibly aid her sister sciences, since biological classification is more concrete than any other, being based on ascertained causal sequence or common descent. Other classifications are of value in proportion as

* "* * * * the *law of heredity*, would, if nothing interfered, keep the descendants perfectly true to the physical characters of their ancestors; they would breed true and be exactly alike."—*Coues.*

"Were it possible for growth to take place under absolutely constant external influences, variation would not occur. * * *"—*Weismann.*

they serve a similar purpose. When the causal relations are prominent the analogy with biology may be close; in other instances the resemblance is only formal; the categories or grand divisions become mere abstractions, and the resulting association of facts follows no natural sequence. Philosophers who have sought to frame ultimate classifications have largely neglected to take advantage of the concrete basis of arrangement afforded by the coherence of the biological series.

To integrate everything to the unity of a single 'substance' or 'principle' (monism) is an idealization of mathematical concepts for which no objective reasons have been adduced. Matter, life and person* appear, as yet, to be final categories of phenomena, comprising different series of properties and meriting separate vocabularies. The second and third categories are not, it is true, independent of the first or of each other, but no causal nexus has been established. Matter gives us elsewhere no hint of the power of vital coordination, and consciousness is no necessary part or consequence of biological evolution. The materialist defines matter so as to include the other categories, while the idealist would annex the universe to the realm of thought. From the middle ground of biology it is apparent that such assumptions are devoid of practical meaning, in that they correspond to no perception based on objective experience. It is easy to say 'protoplasm is a chemical compound' or 'matter thinks,' but these integrations are born of the confusion of words rather than of the conception of ascertained facts. The chemist will find that protoplasm is not a single compound, but an ever-varying infinity of compounds, each capable of work of which 'unorganized' matter has given no suggestion. Neither is it necessary to confuse deliberate purpose with chemical affinity or physical reaction, in the vain attempt at the construction of a specious universal equation.

Students of nature have labored mightily, and they must also wait patiently. Science is advanced neither by disconnected particulars nor by meaningless generalities; all possible associations of facts are to be considered, but essential distinctions must not be neglected and the unlike confused. To recognize biological phenomena as distinct from those of physics does not require belief in an intermittent creation or a polytheistic theology, as suggested by Professor Lankester; the diversity is not lessened by ascribing it to gradual changes which both the physical conditions and the organisms have experienced 'since life began,' whatever that may mean. And until we know vastly more than we do about life and matter, nothing is to be gained by confusing either the phenomena or the vocabularies of biology and physics. Science observes, classifies and interprets facts, with the assistance of language, but neither facts nor words are science by themselves.

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WASHINGTON, D. C.
October 16, 1903.

* As a designation for the third category of phenomena this term, though open to many objections, seems preferable to consciousness, as being at once more general and more particular. Consciousness is a property of person as inertia is a property of matter and evolution a property of life; in this sense consciousness does not become synonymous with intelligence, memory, instinct or mere protoplasmic irritability, as sometimes implied by Minot and other biological writers. Instincts, and even mental arts, such as language, are attainable without subjective intelligence or deliberate thought.

AGRICULTURAL EXHIBITS AT ST. LOUIS.

A PAMPHLET has been issued containing a description of the collective exhibit of the colleges of agriculture and mechanic arts and the agricultural experiment stations of the United States in the Palace of Education at the Louisiana Purchase Exposition. The exhibit, as the pamphlet explains, is intended to illustrate the progress of education and research in agriculture and the mechanic arts in the United States, showing those distinctive features of the work of the land-grant colleges and experiment stations which differentiate them from other educational and scientific institutions. It is probably the most complete and comprehensive display of its kind that has ever been attempted and is believed