tacea it must be placed in the Scaphellidæ. The chief distinctive characters of this family, beside the conditions of the larval shell and the absence of an operculum, appear, from Woodward's researches, to be the extreme condensation of the chief ganglia around the gullet, the development of a very large œsophageal cæcum (which led Poiret to suppose *Halia* had a double œsophagus), and two pairs of preneural salivary glands. If the family is divided into two subfamilies on the basis of the radula, Volutomitrinæ with a unicuspid median tooth, will include *Amoria*, *Volutomitra* and *Halia;* while Scaphellinæ with a tricuspid tooth will include the others. The typical *Voluta* and *Lyria* have wide rhachidian teeth with many cusps, an operculum, shelly protoconch, and other characters which separate them entirely from the Scaphellidæ. According to our present knowledge one of the most important results of Mr. Woodward's labors is to show that the old family of Volutidæ included many diverse types, and that a great deal remains to be done before we can proceed to generalize with safety on those of which the nepionic stages and anatomy are unknown.

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## *RICHTER AND THE PERIODIC SYSTEM.**

A VERY remarkable work appeared at the close of the last century. This was 'Die Anfangs-gründe der Stöchyometrie,' by J. B. Richter, the first volume of which appeared in 1792, and the third and last volume in 1794. In this book we have the first definite statement of the law of proportionality, and some have thought that they have found in it also the Atomic Theory, though it was not claimed that this theory was definitely stated.

Richter's work attracted attention at the time because of his defense in it of the phlogistic theory and it was vigorously attacked by the supporters of the New Chemistry, who followed Lavoisier and the French chemists. The deeper purport of the book and the new ideas advanced do not seem to have been well understood or to have been largely commented upon. Fischer, who in 1802 translated into German Berthollet's 'Statique Chimique,' was apparently the first to draw general attention to the work of Richter and to its bearing upon the conclusions drawn by Berthollet. This latter chemist and Guyton de Morveau acknowledged that Richter had anticipated them in the inference to be drawn from the permanence of neutrality after the decomposition of certain neutral salts and the possibility of calculating beforehand the composition of the salts produced. The discovery of the law of proportionality was a most important one and Richter must, therefore, be regarded as a very remarkable man. In his discovery that the amounts of different metals combining with a given weight of acid combine with a fixed amount of oxygen, he went a step further, anticipating the work of Gay Lussac, and when he established the fact that such metals as iron and mercury have the power of combining with oxygen in several proportions, showing different degrees of oxidation, he was several years ahead of Proust and verged upon the discovery of the law of multiple proportions.

With all his ability to see deeply into the workings of natural phenomena, Richter was not a clear and logical thinker. Wurtz rightly speaks of him as 'the profound but perplexed author of the great discovery of proportionality.' He was confused by his adherence to the illogical phlogistic theories which were becoming each year more untenable. He was further hampered by his determination to give a mathematical foundation to the science of chemistry and to express all chemical changes by formulæ

* Read before N. C. Section, Amer. Chem. Soc., Nov. 9, 1900.

and equations worked out along algebraic lines. It was, doubtless, the presence of these mathematical equations all through his volumes which deterred many chemists from a full and patient examination of them for the kernel of truth which they might contain. The average experimental chemist is not much attracted by abstruse mathematical speculations.

Later chemists commenting upon his work have made some mention of the mathematical regularities observed by him and this led me to think that perhaps Richter might have caught some glimpse of the periodic law before the conception of the atom and the atomic theory had entered into chemistry. To investigate this question it was necessary to examine Richter's writings and I was fortunate enough to secure the use of a copy of his Stöchyometrie through the courtesy of the librarian of the American Academy of Arts and Sciences.

It is of interest, first, to see how near an approach Richter made to the conception of atoms. In the preface to Volume I. the question of solution is discussed and the statement is made that "the chemist cannot boast of being able in any manner to divide a body up into the smallest parts because matter can be thought of as infinitely divisible." From many passages one may judge, however, that he held to the corpusclar view of matter, namely that it was composed of certain very small, discrete particles, which were, however, conceivably further divisible. Thus in giving the various definitions of elements he says that to one chemist the word meant the simplest indestructible substance, the subtlest material which the creator had created for the formation of all other bodies; to another it meant such materials as could not be decomposed into dissimilar particles and in which no component particles could be recognized. For himself he prefers to divorce the word from all connection with primal matter, or Urstoffe, and to make use of it simply as a part of the chemical technology, attaching to it the meaning of a body undecomposable by any means known to the chemist. Chemistry as an art, according to Richter, consisted in the ability to separate elements from one another and to bring them together as constituents of a new body. Chemistry as a science was something greater, including its theories and fundamental axioms. A chemical element, he says, is one which, without being decomposed into unlike parts, can by mixing with other kinds of matter cloak their peculiar characteristics and bring about others. It is *elementum immediatum* when it cannot be decomposed into unlike parts; *mediatum* when it can be thus decomposed (p. 5 seq.).

Thus, as Richter adds in a footnote, vitriolic acid is an *elementum immediatum*, since no one has been able to decompose it into unlike parts, but sulphur is an *elementum mediatum*, since any one knows that it can be decomposed into vitriolic acid and phlogiston and reformed from these two. This is of interest as showing the degree of knowledge on which he based his reasoning. His corpuscles are called 'Theilganzen,' and in these the force of affinity resides. Thus he states, "to each infinitely small particle of the mass of an element there belongs an infinitely small portion of the chemically-attracting force of affinity" (p. 123).

The part of Richter's work which appears to refer most nearly to the periodic system is found in his second volume on page vi of the preface. He refers to the fact that the supposition had already been made in a paper on the 'Newer Objects of Chemistry, especially the recently discovered half-metal Uranium,' that the affinities of many chemical elements towards any single one might be in a definite progression. This supposition, says Richter, has already in the case of four quantitative series been raised to the dignity of an incontrovertible rule. The tables of masses form arithmetical progressions and the affinities of the elements which belong to the series, proceed also, in so far as they are not disturbed by the indwelling elementary fire, in the order of the masses. Besides one is in position to see the probability of many homogeneous elements present in nature. Also the doubled affinities proceed in arithmetical progression and with careful observations one can scarce resist the thought that *the entire chemical system consists of similar progressions.*

It is well to examine a series given by Richter to get more fully at his meaning. Thus in the same volume, page 28, he gives the masses of the alkaline earths which neutralize 1,000 parts of hydrochloric acid.

| | | |
|---|---|---|
| Magnesia | $734 = a$ | |
| Lime | $858 = a + b$ | $(734 + 124\frac{1}{2} = 858\frac{1}{2})$ |
| Alumina | $1{,}107 = a + 3b$ | $(734 + 3 \times 124\frac{1}{2} = 1{,}107\frac{1}{2})$ |
| | $= a + 5b$ | $(734 + 5 \times 124\frac{1}{2} = 1{,}356\frac{1}{2})$ |
| | $= a + 7b$ | $(734 + 5 \times 124\frac{1}{2} = 1{,}605\frac{1}{2})$, |
| | etc. | |
| Baryta | $3{,}099 = a + 19b$ | $(734 + 19 \times 124\frac{1}{2} = 3{,}099\frac{1}{2})$ |

Similar series are given for the alkalies and alkaline earths with the different acids. Again these tables are compared with one another and thus was brought out the law of proportionality. One of the most remarkable regularities is obtained by examining the differences in the masses in such a series made up of observed combining numbers of known elements and interpolated combining numbers of hypothetical elements. Thus (p. 38):

$$616 - 526 = 90 \quad = 1 \times 90$$
$$796 - 526 = 270 = 3 \times 90$$
$$973 - 526 = 447 = 5 \times 90 - 3$$
$$1{,}152 - 526 = 626 = 7 \times 90 - 4$$
$$1{,}330 - 526 = 804 = 9 \times 90 - 6$$

etc., etc.

Of course, it is readily seen that all these regularities are more in the line of the triads of Döbereiner or the later work of Dumas than the periodic system. But a close examination reveals something more —a really deeper insight into the nature of the elements which is marvellous when one considers that Richter was dealing with compounds not elements, and with combining numbers and not atomic weights. First, one must note his statement of the belief that 'the entire chemical system consists of like progressions.' To his mind the elements formed a system correlated and made up of progressions. This is, of course, not the ascending series of de Chancourtois and Newlands, but it seems to me a position much nearer to it than was reached by any chemist for more than half a century afterwards.

Again, in other portions of this volume Richter speaks of the necessity of deducing quality from quantity and vice versa. Thus he points out that the series of masses mentioned as forming arithmetical progressions are really series of affinities also, and the relative affinities might be deduced from the relative masses. Much space is given also to the effort at tracing relationships of the specific gravities. While it cannot be positively stated that Richter foresaw that important part of the periodic law that the properties of the elements are dependent upon the weights, he seems at least to have been possessed with the idea that what he called the masses of the elements had something to do with what he considered the qualities, or that they progressed similarly. And that they in the main progress similarly is about all that we know with regard to them at the present day.

I acknowledge that there is some difficulty in sifting out Richter's full meaning from the mass of mathematical calculation and one must be careful to avoid reading into his work the thought of later years. It is not strange that the tedium of following such involved calculations and speculations as his should have deterred his contemporaries from following his trend of thought or paying much attention to him. It cannot be claimed that he preceded Dalton in his conception of the Atomic Theory, but Richter belongs to the number of the great original thinkers of chemistry and it is time that greater justice be done him.

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*VERTEBRAL FORMULA OF DIPLODOCUS (MARSH).*

THE splendid skeleton of Diplodocus, discovered in the Como Bluffs of Wyoming by the American Museum party of 1897, has enabled Professor Osborn to very materially increase our knowledge of the osteology of that genus.* Interesting and unique as was the material that formed the basis of Professor Osborn's memoir, it nevertheless left many questions unsettled concerning the osteology of Diplodocus. In 1899 a second skeleton was discovered in the Dinosaur beds of the Upper Jurassic, near Sheep Creek, in Albany County, Wyoming, by Dr. J. L. Wortman, while engaged as Curator of Vertebrate Paleontology of this Museum, in exploring the fossil-bearing horizons of that region.

The second skeleton of Diplodocus was very carefully exhumed under the skillful direction of Dr. Wortman, and has since been entirely freed from the matrix and temporarily mounted by Mr. A. S. Coggeshall, Chief Preparator in the Department of Paleontology.

Now that this material is available for study, it proves to supplement in a remarkable manner the skeleton belonging to the American Museum. A detailed description of our material will be given in a paper by the writer which it is proposed to have appear among the memoirs of this institution. In the present note only the vertebral column will be considered, and no attempt will be made to describe this in detail, but rather to correct some errors concerning the vertebral formula of Diplodocus as given by Osborn in his memoir cited above, and by Dr. W. J. Holland, in a subsequent paper entitled 'The Vertebral Formula in Diplodocus, Marsh,' published in this JOURNAL, May 25, 1900, and based upon the material now under discussion.

About 45 feet (14 meters) of the vertebral column is preserved in our specimen. When discovered the vertebræ did not lie in a connected and unbroken series, yet there can be little doubt that they all pertain to the same individual, and they have been mounted as a continuous series commencing with the axis and ending with the twelfth caudal. In all 41 vertebræ are represented, including 14 cervicals (all but the atlas), 11 dorsals, 4 sacrals and 12 caudals.

Assuming that no vertebræ are missing from our series the vertebral formula of Diplodocus should now be written as follows:

Cervicals, 15.
Dorsals, 11.
Sacrals, 4.
Caudals, 37, as estimated by Osborn, not 35, as attributed to him by Holland.

The above vertebral formula will be seen to differ from that given by Holland, the latest contributor on this subject, as follows:

1. The number of cervicals is at least 15.
2. There are 11 dorsals instead of 10, as fixed by Holland, who mistook the first presacral of Osborn for a sacral.

There are 4 sacrals, as given by Osborn and Holland, while the number of caudals is still placed at 37, as estimated by Osborn. Of the caudals, only the 12 anterior are preserved in our skeleton, and the second and third of these have coossified centra.

In placing the number of dorsals at 11, I am assuming that Osborn is right in considering the first vertebra with a free spine,

* See 'A Skeleton of Diplodocus,' Part V., Vol. I., Mem. Am. Mus. Nat. Hist., pp. 191–214