small quantity of water in a rubber finger-stall, which is pressed periodically by the finger?

As an alternative to external presure of the rubber balloon I have experimented with one balloon inside another containing fluid, and the sounds produced by periodically increasing the distension of the inner one are wonderfully exact reproductions of the sounds of the heart.

ART. XIII.—*Some Suggestions in Micro-Biometrics.* By EDWIN WOOTON, Author of "The Metabolism of Senile Decay," "Renal Excreta," and other Researches.

ALTHOUGH the many improvements that recent years have witnessed in the methods and materia of microscopic study have given histology a high place among the sciences, and the visible characters of minute structures are matters of fairly advanced knowledge, there obtains a factor concerning which our teaching is crudely inchoate : the relativity of concrete quantities.

Our text-books and monographs deal with these either by the metric or the ordinary arithmetical system. We are taught that a cell measures so many mikrons, or fractions of a millimetre or of an inch, linearly, superficially, or cubically. We are taught also in each case either that the measurements range from a stated figure to another, or we are given that most loathful compromise—an "average."

When all these details have been tabulated, we see a series of quantities having no more apparent relation to one another than those in a shopkeeper's price list. So far as I am aware, it has never been advanced that they have an inter-ratio. They form a wilderness of crudities, and, for aught that a philosophical student can see to the contrary, they might be doubled, halved, or totally neglected without in the least affecting his acquaintance with the laws of life.

In the study of macro-biometrics we have at the very outset the common knowledge that a normally formed human body has a certain number of legs, arms, fingers, toes, and other parts; that there are tall people and short people, big heads and small heads; and our studies lead us to further certainties less obvious: the best ratios between bodily parts, and the conditions modifying such ratios.

The entire study of biology conducts one at each step nearer to the belief that for each obtaining concrete fact there is a physical causation; that beaks, fins, feathers, horns, poison glands, and cerebral convolutions are but the material consequences of responsive adjustments to ceaseless stimuli; and that as nothing obtains without a cause, so for each biological truth there is a purpose; it is never in itself—finality.

Then, how comes it that when dealing with tissue elements we have acted as if such lessons had never been learnt? Are we to think that while the length of a limb, the diameter of an ocular pupil, and the obtaining ratios of macro-structures in general result from law, the principle of proportion does not subsist between structural elements? Is not such a supposition a self-disproving absurdity? If true, it would be a solecism in nature. The coarser structure is but a product of structural tissue units, just as the chemical character of a ton of calcium-sulphide is an expression of its molecules.

I submit that the chaos is a consequence of our methods of measurement obscuring the truth.

These methods are purely arbitrary, and of necessity they give factitious results. It does not affect the question whether one uses the metric or, in this country, the more popular system. In either case the calculations are arithmetical throughout, and Nature does not so work.

One might as well attempt to solve the problems of crystallography or chemistry by arithmetic as those of biology. Arithmetical computations are true only when the units dealt with progress arithmetically. If they progress geometrically, or by multiples, and no practical recognition

is extended to the fact, arithmetic becomes the mother of falsity.

Had chemical philosophy never advanced beyond the arithmetical stage, where would its law of combining proportion be?—still in the secret archives of Nature. One may analyse an ounce or a ton of a compound and find so much of each constituent, and yet be totally in the dark as to there being any such law. He who would master even the simplest outlines of chemistry must seek for the units and ratios, as did the chemical discoverers—in chemistry itself. He may not bring to his study a method of computation foreign to it.

Such considerations are equally true in physics. To the man unfamiliar with the laws of motion it seems the teaching of common sense that if a missile is discharged vertically at ten feet a second it will attain five hundred feet in fifty seconds.

To work solely by arithmetic in any of the sciences that deal with laws of nature is to reason rightly on erroneous premises, with, of course, error for consequence.

Quite apart from such considerations, very grave objections can be raised to the employment of our ordinary abstract quantities. All fractions are negative. A quantity that is to be handled, using a figure of speech, a score of times daily, that has to be clearly mentalised, and conveyed to the mentality of others, should be a positive unit or multiple of units, of which the mind can on the instant form a clear concept. What sort of idea is afforded by .000057 mm.? On paper it is nebulous, and verbally it is wasted breath. Inch fractions are equally useless. As specimens, take the diameters of a red and a white blood cell = $\frac{1}{3200}$ and $\frac{1}{2500}$. The fact that they have no common denominator renders comparison mentally meaningless to those who have not worked out the ratio of the fractions.

To a limited extent the introduction of the mikron has remedied the difficulty, so far as the metric system is concerned. But to get the right mental grip one should treat it and its multiples

as positive. If we say, a thousand mikrons make a millimetre, and a thousand millimetres make one metre, we have materials for giving a clear mental picture of any linear measurement that has to be stated. But to do this effectively we need a concrete unit that the mikron shall represent, and hitherto not one has been suggested.

The metric system is the best possible for multiples of the metre; for fractions of the millimetre it is a complete failure.

Inch fractions are almost unusable when teaching. Not seldom, one has to remind the pupil that the larger the denominator the smaller is the object. Sometimes these fractions crystallise grotesquely in a pupil's mind. The two cited above are examples. The unfortunate student, fogged by the thousand and one things he has to commit to memory, thinks of the cells as measuring thirty-two one-hundredths and twenty-five one-hundredths respectively!

Is there a true biological mode of progression operative in the human organism?

We know, of course, that chemically the body works under ordinary chemical law, and that chemical progression is by multiples of molecular weight, and we have no reason to suppose that in the microcosm the laws of physics are specifically modified. The progression, if it obtain, will be in all probability cytological.

Yet, for the reason that the human body *is* a microcosm, exhibiting in all its modes of working the laws that govern the outer universe, it is only reasonable to expect that cytological progression—if a fact—will have impressed its character on every such law. We should expect to see in its electric, chemical, and other life factors some clue to inter-cellular ratio.

Hence, the natural divisions for research are many. The relation of calorics to numerical cellular units, the relation of molecular weight to calorics, the electric potential of muscle mass, and the relation of potential to cell number are but examples.

As restricted time and limitation of space will not admit

of anything even approaching an exhaustive treatment of the subject, and as my aims are rather to exemplify what I believe to be truths than to adduce a huge mass of data, I shall deal only with a few salient facts, taken almost at hazard, from the host I have collated. In doing so, I would lay stress on the statement that I am unacquainted with a single fact inimical to the reasoning here advanced.

Before going further, it may be well to say that this article has nothing in its character even tangent to the occult or mystic. If I should show that certain numbers have power in the living body I shall be wandering from the highway of the physical no more greatly than the chemist when he writes down the invariable molecular weight of iron.

One of the most important conditions of life-tenure is time. It would be needless to labour the point how it indicates the expectancy of parturition, teething, puberty, adult vigour, and senility.

But there is not only a time astronomical; there is, I submit, one essentially biological. The calculations of the astronomer by which he marks the years agree with biology only in regard to the day unit. In human biology the very first temporal quantity is that of gestation—280 days. The menses occur every twenty-eighth day. Seven is a factor in both numbers. Seven is also found in the ratio of the usual number of menstrual days to 280, which is forty. Medical men of good repute have stated that with most women the menses occur during the first seven days of the moon's age.

The salivary glands become physiologically active about 280 days after birth. The cutting of the milk teeth corresponds in periods of days to multiples of seven. The thymus gland begins to atrophy at about the seventh period of 280 days from birth, corresponding to the sixth astronomical year of life. Thirty-five such periods, that is, five multiples of seven, equal the first twenty-six common years, whose completion synchronises with that of bodily development. In eastern countries—the cradle home of

humanity—puberty is attained in about fourteen such biological, or ten common years. One could multiply data, but I think sufficient have been adduced to warrant the conclusions that we have a true biological year of 280 days, that its multiples and dividends correspond with physiological stages, and that in all such numbers we have the factor seven.

Equally true is it that seven is to be found in the cardiac-respiratory ratio. The normal pulse is usually given as 72, and the respiratory frequency as 18; but a moment's thought will show that there are more nearly 70 respirations to 280 pulse-beats; the ratio being that of ten sevens to forty sevens.

The total capacity of the capillaries is 700 times that of the aorta, or seven aortic capacities, multiplied by one hundred.

The ratio between the number of complete blood circulations to pulse-beats works out as 7 to 126. One complete circulation occupies 15 seconds. The number of pulse-beats corresponding to this time is 18; therefore, 7 circulations agree with 126 pulse-beats.

Any attempt at an exhaustive research into the ratios of histological units must take account of mass; but for the purpose I have immediately in view it will be better to deal with the more generally known linear measurement.

Before going further we may ask how any number-unit would in the nature of things be affected by the molecular constitution of the body? It must be held in mind that our molecular ultimates are so small that aggregates of six, eight, or even nine would, when multiplied by billions, give aggregates of the coarse or visible kind scarcely, if at all, distinguishable from seven. Moreover, we may be dealing with molecular aggregates in each of which there are molecules of differing numerical value. From either would arise what I may term "fluctuation." The gross values would circulate round a central figure, sometimes only exactly agreeing with it.

As a fact, that is just what does obtain.

Hence, in dealing with seven as a tentative unit it will be helpful if we represent it by some such symbol as (+7-).

I suggest that the starting concrete point of our calculations be the germinal nucleolus. It has not an unvarying size, but in a well matured ovum it has a fairly constant ratio to the nucleus. Histologists usually assign seven mikrons to the diameter of the nucleolus, and fifty to that of the nucleus. In accordance with the principle of fluctuation we will write the proportions as 1 to (+7-).

In the course of our work we shall have to do with structures smaller than the nucleolus, and we must make provision for the not improbable contingency of our becoming familiar with structures more minute than have yet been distinguished. It will, therefore, be convenient to introduce an abstract unit of measurement, and we will call it a *bion*. Recognising that our only tentative guide to ratio is the number seven, we will make one bion the seventh part of a mikron.

Now, keeping to the nucleolus as our concrete unit, and always giving our factor seven the value (+7-), we could estimate the proportion between the nucleolus and other structural elements, and by this means we might arrive at something approximating verity as to the laws governing the multiples or dividends of seven in body-building; but it would necessitate a radical revision of every biological measurement. In effect, it would replace the metric system by another. As a matter of convenience it may be well to avoid this. Some revision will be essential, but by still giving a place to the millimetre we shall at the outset find matters run more smoothly.

That the diameter of the nucleolus is seven mikrons is a most happy, fortuitous agreement with the principle on which we are working, for we have = nucleolus, 7×7, nucleus $7 \times 7 \times 7$.

Physiologists give the weight of body blood relative to body weight as near the thirteenth; that will agree with our fluctuating value, being $(+7-) \div 2$. They give

the weight percentage of hæmoglobin in the blood as about a thirteenth; that also will agree with $(+7-)$. The percentage of iron in hæmoglobin is (roughly) .4, that is one part in two hundred and fifty, which agrees with $(+7-)\times 37$.

Muscle-weight relative to body-weight is 42 per cent., or three-sevenths. The body contains about 64 per cent. of water, that is $4\frac{1}{2}$-sevenths; and 21 per cent. of protein is in muscle, equalling $(+7-)\times 1\frac{1}{2}$. Muscle contains somewhere round 75 per cent. of water, or five-sevenths.

In all these computations it must be kept in mind that the analyses vary. They all, however, show the number seven constantly as a ratio or prime factor in a ratio.

We may take the nitrogen output of the skin relative to the total output as 1 to 21, or as 1 to $(+7-)\times 3$.

It has been calculated that there are approximately three hundred and fifty-five millions of alveoli in the human lungs, which number, allowing for errors, is a multiple of seven.

The primordial ovarian follicles of the newly-born child are seventy thousand in number.

Anyone even superficially acquainted with the human body could answer my argument by the production of seemingly controverting facts. He could say, for instance:—Here are three structural elements having the respective diameters eleven, twelve, and seventeen mikrons. Where is your seven factor?

My answer would be that if we honestly find the seven factor does obtain in a sufficiently large number of activities and structures to warrant any attention at all we shall be acting in the true spirit of science if we seek for an explanation of such apparent irreconcilables rather than if we regard them as things insuperable. In a case such as that just advanced we have but to introduce the multiple that we have already found to be operative in other ratios, and we shall see the possibility of 77, 84, and 119 being the ratios obtaining here. Expressed in terms of seven, they would be $=(+7-)\times 11$, $(+7-)\times 12$, $(+7-)\times 17$.

Here are a few other constants :—The sweat glands of the surface have a diameter of coil ranging from .7 to .35 mm. In the axilla they are much larger, but in each case their size is a multiple of (+7-).

Let me advise the captious reader not to exclaim that I have already stated such measurements to be in character, as in effect, factitious. They are such; it is in the relation of the measurements to other measurements that the ratios of the concrete things are to be found.

Sound is an interpretation of vibrations, and the seven notes of the scale are physiological facts. The cells of the anterior horn of the spinal cord = 135 mikrons in diameter. The minute fusiform cells of the retina have a diameter of 10 mikrons. The ratio, as 10 to $13\frac{1}{2}$, may be expressed as 10 to $(+7\dot{-})\times 2$. The radial width of the basilar membrane, measured from the entrance of the nerve fibres to the spiral ligament, is = 3 mm. × (+ 7 -) in the basal whorl, 5 mm. × (+ 7 -) in the middle whorl, and 5 mm. × (+ 7 -) in the topmost whorl.

The number of inner hair cells has been estimated at 3,500, that is 500 × (+7-). The outer rods of Corti are 800 × (+7-), and the inner rods are 550 × (+7-).

It is quite in harmony with the facts adduced that while the ratios between (1) the length of the trunk, and the limbs, and (2) the weights of internal organs, and (3) the measurements of such organs contain the factor (+7-), we often see it absent in the girth measurements of limbs and trunk and neck. It is to be remembered that these last are often expressive of purely factitious or fortuitous conditions. A course of physical culture, over-feeding, or insufficiency of diet will totally obscure any original ratios. Thus, although the female trachea in proportion to that of the male is in its transverse diameter as 18 to 21, or 6 to 7, the neck girth measurements and their ratios are as variable as luck itself.

If, pursuing his inquiries carefully through a series as lengthy as he may deem needful, the physiologist shall find the obtainment of the seven or any other ratio to be a law of the organism, he will not be making a hazardous guess

in believing that probability points to it as a factor in metabolism itself.

Here are a few more suggestive data :—

As one respiration occupies 3.33 seconds, and one pulse beat occupies .833 seconds, the ratio of respiration to pulse beat is as one to four, or (+ 7 -) to 28. The ratio of the auricular systole to the ventricular is 1 to (+ 7 -). As nerve force travelling at 35 metres a second passes through the body of a man of six feet in .19 seconds, and there are 12 muscular contractions per second, the ratio in point of work is .631 of a contraction to one nerve current unit, and in point of time as .083 second to .19 second. The ratio of the cardiac systole to muscular contraction is as 9 to 6, or as one muscular contraction to .15 systole. (Compare with .15 of circulation in one second.)

As a man of about twelve stones in weight has a right ventricular capacity that may be set down as three fluid ounces, the entire blood of his body—which will be close upon 208 ounces—must pass through the ventricle in 69.9 beats. The smaller the body, the less the capacity of the ventricle, and the less the blood quantity. The ratio will be found to keep its integrity. Hence, seventy beats may be held to constitute a true physiological work unit.

Taking the biological year as 280 days, and the astronomical as 365 days, we have $\frac{280}{365} = .767$.

Taking the pulse as 72 per minute, and the minute as 60 seconds, we have $\frac{60}{72} = .833$.

The difference between the ratios is only .066. Allowing for physiological fluctuations, the fractions are identical. We may therefore say that as the pulse is to the minute, so is the biological year to the astronomical.

The human body presents no single instance of a mathematically exact and invariable constant. In periodicity, chemical constitution, measurement, and weight we see only limited variants.

Whether we take an average, a dominating—that is a "usual" quantity—or state the variations we shall

find three factors most frequently operative :—3, 5, and 7. Seven could be expressed by $(+3-) \times 2$.

In some cases five appears to fit more exactly than seven. It may be that each of these three is a unit number. Only a long and careful series of computations can determine the point. I am not holding a brief for Seven, save as expressive of the truth that multiple progression obtains. That truth is placed beyond all questioning by periodicity. The ratios are too marked, and the functions too vital for the former to have no significance. And it should be kept in mind that every observable function is a summation. Hence all relativities of adult life might be expected to obtain from the very incidence of the embryonic, as do the more obvious characters that make up physical personality.

As yet we do not know what lies between the chemical molecule and the cell; but the obtainment of any ratio number points to it as expressing a unit of progression; and the inquirer will not wander far from the right path if he grasps it as a clue that shall guide him in investigating the constitution of the cell itself. For, as the greater is but the lesser greatly multiplied, so must any numerical factor found as a "constant" in the greater be operative in the genesis of the body's structural units.

PERISCOPE.

THE DOG AS A CARRIER OF DISEASE.

The United States of America Department of Agriculture has issued a valuable paper (*Pacific Medical Journal*, Vol. LIX., No. 2) on the dog as a carrier of disease. Of the diseases carried to stock by dogs, the foot and mouth disease is probably of the greatest interest at this time. The virus of the disease is carried on the feet of the animal from the affected farm to other farms, and thus the disease is spread to neighbouring herds. In Bulletin 20 of the Agricultural Department it is pointed out that dogs convey rabies, hydatids, ringworm, favus, tapeworm, roundworm, and occasionally—by fleas and ticks—bubonic plague or the deadly "spotted fever" to human beings.