the great question, yet is he confident that as each generation adds a little certain knowledge to the world, there may come in time an accumulation of facts regarding living substances, so complete that while the great mystery voiced in that greatest of scientific questions, "What is life?" may not be answered except in its activities and phenomena, there may cease to be the supreme question in its essence.

Through cell structure, simple individualism, greater differentiation, even to highest complexities, biological microscopy leads its devotee. And at each advancing step towards the Great Mystery our appreciation of Luther's statement, "To have studied well is to have prayed well," should increase.

AN EXPERIMENT IN RESONANCE.

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Without doubt the most important things in elementary acoustics are these: (1) Simple Harmonic Motion. (2) The relation between frequency, wave length, and velocity, and all that grows out of it. Consequently the more experimenting the pupil can do along these particular lines, and especially the more elaborately any experiment he does perform can be interpreted by him, the more definite and important will be what he may get out of the subject. Sound is a part of physics frequently more or less neglected, especially in an experimental way, except in so far as it is taught as a collection of curious and interesting phenomena. As a matter of fact, given Melde's experiment, Kundt's experiment, experiments on the vibrations of coiled springs, the tuning fork chronograph, and experiments in resonance, not to mention graphic constructions for simple and complex wave forms and for

Lissajou-figures, the subject becomes the richest laboratory subject in physics from the mechanical standpoint, and also as a preparation for the study of some of the same kinds of motions in light and heat, where the phenomena are not as readily handled in the laboratory, at least by a beginner.

For some of these experiments the question of procuring suitable forks is a serious one, especially if one wishes to make the experiments something more than qualitative or limited in scope by putting variety into them. It then becomes necessary to have several forks or other vibrating bodies to contrast. This applies especially to the experiments on resonance. But here at least we have a very easy way out of the difficulty. Rectangular bars, than which few things can be procured more easily or in greater perfection, will very efficiently take the place of numerous forks and will give all the variety in conditions desired.

An extract from a pupil's note book and a drawing is here given to illustrate this point. More bars might have been advantageously used, a sufficient number perhaps to have covered the notes of the principal chords of the scale.

APPARATUS.—The apparatus was set up as in the figure. *W* is a wooden upright fastened to the table by means of the bracket *b*, and carrying at its upper end the bracket *b*², to which are fastened the clamps that support the vibrating body *B*. To the front of *W* is fastened the glass tube *T*, which tube is connected by means of rubber tubing to the bottle *R* as shown. Raising or lowering *R* changes the level of the water in *T* as may be desired. The bars were of steel of the dimensions given in the table, and were hung from the support by means of strings tied one-fifth of the length of the bar from each end.

OPERATIONS.—The bar under test was struck with a small copper mallet. *R* was raised or lowered until a point was found where the sound was the most strongly reinforced. The level of the water was then read by the aid of a meter stick fastened to the tube. Thus were obtained columns 1, 2 and 3.

	Resonances.			Average $\frac{1}{2}$ Wave Length.	Temperature.	Velocity.	Frequency.	Dimensions.
	Upper.	Lower.	Number Between.					
Fork 128 v. d.	6.5	140.8	0	134.3	20	344	128	
Bar C_4	11.6	97.8	9	8.62	25.8	348	2018	15.7x2.5x9.5
Bar $A b_3$	14	96.8	7	10.35	"	"	1681	24.2x0.6x2.5
Bar $A b_2$	8.7	93.4	3	21.17	"	"	821	32.3x0.6x2.5

The readings and the dimensions are in centimeters, the velocity in meters. The diameter of the tube was 3.7 cm.

CALCULATIONS.—(1) For the fork the maker's stamp of the frequency was taken as correct and the velocity of sound in the tube was calculated from the formula, velocity equals frequency times wave length, where the wave length is twice the distance between the points of resonance. (2) For the bars the theoretical velocity at the observed temperature was taken and the frequencies were calculated from the formula, frequency equals the velocity divided by the wave length, where the wave length equals twice the distance between any two points of reinforcement divided by a number one greater than the number of points of resonance between.

INTERPRETATIONS.—(1) The velocity as calculated from the data given by the fork is 344 meters instead of 344.4 as found by standard authorities, an error of less than 0.2 per cent. Then, if the fundamental formula connecting wave length, frequency, and velocity is true the distance between successive points of reinforcement must be one-half a wave length. (2) From the frequencies found for the bars and the dimensions of the bars, we get the following:

The squares of the lengths of bars Ab_2 and Ab_3 are 1043 and 585.

The ratio of the squares is very nearly 2 to 1.

The ratio of the frequencies is very nearly 1 to 2.

We conclude that in bars supported as these were and caused to vibrate transversely the frequencies are in the inverse ratio to the squares of the lengths, or the frequency varies inversely as the square of the length.

Bars Ab_2 and Ab_3 are an octave apart. The ratio of their frequencies as found is very nearly 2 to 1.

Bars Ab_3 and C_4 are a third apart. The ratio of their frequencies as found is very nearly 4 to 5.

These results agree with the ratios as given in the physical theory of music.