chordae tympani after the administration of eserine regularly produced gastro-intestinal motility. Mere stimulation of the chordae tympani likewise produced motility of the small intestine and the colon. In all 4 dogs in which stimulation of the chordae tympani was performed without previous injection of eserine, motility of the ileum and colon was obtained (Fig. 1). It appears that factors are

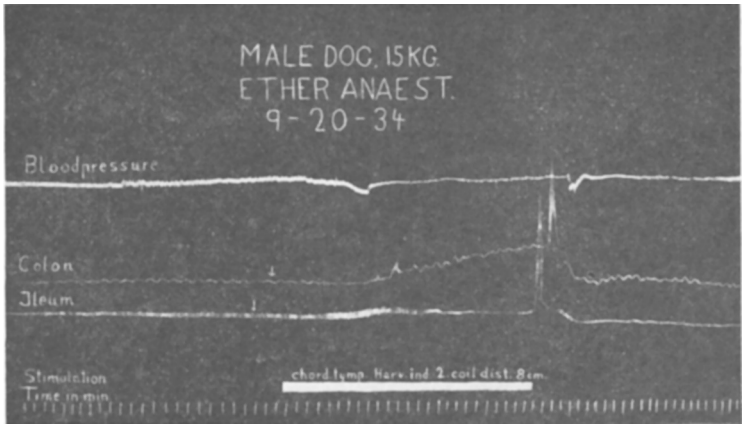

FIG. 1.
The sudden elevation of the curves of the ileum and colon at the end of stimulation of the chorda is due to panting of the dog.

present in the blood which alter the activity of the esterase allowing the acetylcholine liberated by stimulation of the chordae tympani to affect more or less the gastro-intestinal tract and to produce varying degrees of motility. This phase of the investigation is being continued.

7637 C

Total Versus Extra Oxygen Consumption in Muscle Activity in Relation to Fiber Length.

PAUL W. SMITH. (Introduced by M. B. Visscher.)

From the Department of Physiology, College of Medicine, University of Illinois, Chicago.

It appeared to the author that it would be of considerable importance if the fundamental behavior of cardiac and skeletal muscle could be more closely correlated by the explanation of an apparent

difference in their behavior following changes in initial fiber length.

Evans and Hill[1] showed that the heat produced during a short tetanus of the frog's sartorius increases as the muscle is extended rising to a maximum at about the *in situ* resting length, and then decreases upon further extension.

Starling and Visscher,[2] utilizing the isolated heart-lung preparation, showed that the oxygen consumption of the mammalian ventricle rises with increasing diastolic volume, but found no indication of a maximum with subsequent decline, although they explored a very wide range of alterations in ventricular volume. It is obvious that these experiments involved the measurement of the total oxygen requirement of the heart, while in the myothermic experiments quoted above only that excess metabolism due directly to activity was determined.

Feng[3] reported that the resting heat production and oxygen consumption of the frog's sartorius both rise with increase in the length of the muscle. These observations might have been anticipated in the light of the experiments of Clark and White,[4] who showed that the oxygen consumption of the quiescent, filled auricle of the cold blooded heart approached that of the beating, empty auricle.

Frog's sartorii were first measured *in situ* with the limbs in a uniform position, then excised and again measured at the minimum length which they would assume, floating freely in Ringer's fluid. They were soaked in Ringer for 3 hours and their oxygen consumption measured in a microrespirometer of the Thunberg-Fenn type. The respirometer used embodied 2 convenient modifications. The 2 chambers were connected by capillary tubing and a stopcock which could be opened to permit the introduction of oxygen through the apparatus at any time without removing it from the bath. The inserts or stoppers of the muscle chambers consisted of an outer tube continuous with the ground glass stopper, and an inner tube bearing the sealed-in electrodes. The space between was sealed with petrolatum. The muscle was suspended between two lugs or projections, one at the lower end of the inner tube, the other on the outer jacket just below the stopper. This arrangement permitted longitudinal adjustment of the inner tube, and therefore changes in the length of the muscle without removing the apparatus from the

[1] Evans, C. L., and Hill, A. V., *J. Physiol.*, 1914, **49**, 10.

[2] Starling, E. H., and Visscher, M. B., *J. Physiol.*, 1927, **62**, 243.

[3] Feng, T. P., *J. Physiol.*, 1932, **74**, 441.

[4] Clark, A. J., and White, A. C., *J. Physiol.*, 1929, **68**, 406.

constant-temperature bath. The inner tube was immobilized by means of a short sheath of heavy rubber tubing surrounding both the inner tube and the top of the outer jacket, thus preventing movement during contraction of the muscle.

The muscle was placed in the respirometer at its shortest length and the resting oxygen consumption measured. Ten maximal, break-induced shocks were then delivered directly to the muscle at a rate of 1 per second, and the excess oxygen requirement due to the isometric contractions thus determined. When the oxygen consumption had returned to the original resting rate, the muscle was extended by regular steps, usually 3 to 4 mm., and both resting and activity oxygen usage determined at each length. A control determination was made by returning the muscle to its first length at the end of the experiment.

The results of a typical experiment are presented in Fig. 1. The activity oxygen consumption was found to rise to a maximum at a length of 124% of the minimum length (100%) and to decline upon a further extension to 136.5% of the minimum length. The resting oxygen consumption continued to rise upon extension with an actual increase in steepness of the curve beyond the 124% length. This upturn in the resting oxygen usage was a quite uniform finding. Since muscles returned to their original length at the end of the

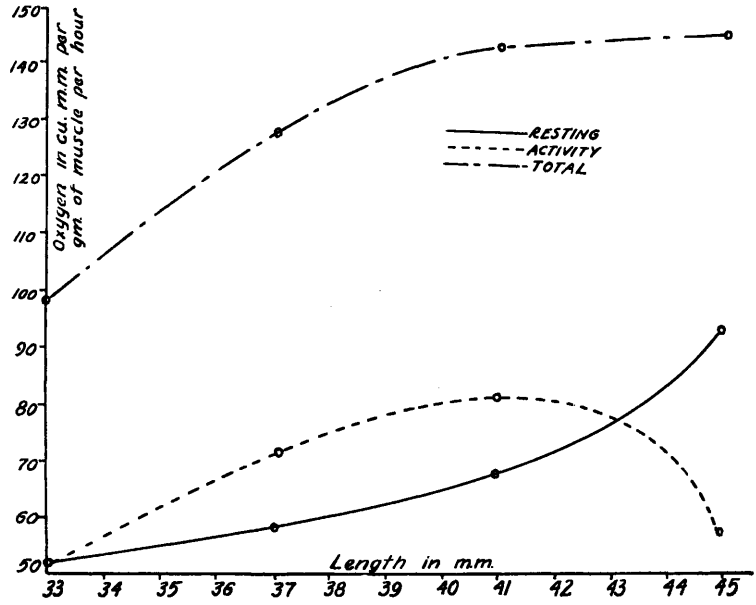

FIG. 1

experiment returned also to approximately their original oxygen usage, it is not believed that this is an indication of actual injury.

The *total* oxygen requirement continued to increase with extension of the muscle, in the majority of experiments approximating closely a straight line. Fig. 2 presents the protocol of this experiment, showing the actual capillary readings in millimeters of movement in 10 minutes plotted along a time axis.

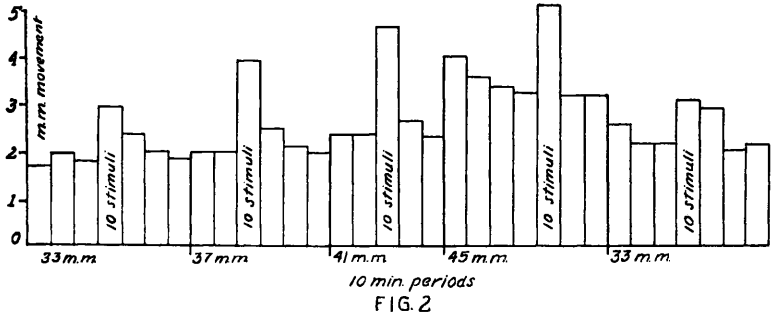

FIG. 2

TABLE I.

Experiment No. 1. Length *in situ*, 39 mm., on Ringer 35 mm. Weight, 0.100 gm. Temperature, 25° C. Oxygen in cu. mm. per gram of muscle per hour.

Length in mm.	36	39	42	46	39
Resting O_2	48	51	54	87	48
Activity O_2	57	63	66	45	
Total O_2	105	114	120	132	

In Table I are given the oxygen consumption data from a second typical experiment, in which the total oxygen requirement follows a perfectly straight line up to an extension of 28.5% over the minimum length.

It would appear from these data that the response of both cardiac and skeletal muscle to increase in fiber length is, in fact, identical, since that portion of the metabolism not directly associated with recovery from activity becomes an increasingly significant part of the total metabolism at appreciably increased initial fiber length.