

They may be numerically evaluated by solving the general equation

$$\theta = a\epsilon^2 + b\sqrt{\epsilon}$$

for the two sets of experimental values of θ and ϵ from a setting curve, preferably in proximity to the maximum set point, or approximately by substituting the values of θ_i , the initial setting time, and θ_f , the final setting time, in the following equations:

$$a = 0.0654 \theta_f - 0.1850 \theta_i$$

$$\text{and } b = 5.918 \theta_i - 0.925 \theta_f.$$

Experimental values for these functions have been obtained in a number of cases. Under specified operating conditions, these, such as are given in Table I, may be related to the chemical composition of a particular series of hydraulic limes.

TABLE I

Differentiation of setting characteristics

Sample	Water %	Max. set point		Characteristic Functions at θ', ϵ'		<i>a</i>	<i>b</i>
		θ'	ϵ'	P-Set	H-Set		
		Sec.	cm.	θ_1	θ_2		
A	83	812	1.2	90	722	62.7	659
B	82	1223	2.1	136	1087	30.8	750
C	85	1598	1.6	178	1420	69.4	1123

1. Ferrari, F., *Cemento Armato*, 1937, 51.
2. Malquori, G., *Ricerca Sci.*, 1936, 7 (2), 440.
3. Santarelli, L. and Guzzini, A., *Ind. Ital. Cemento*, 1951, 21, 83.
4. —, and Senesi, A., *Rend. Soc. Mineral. Ital.*, 1949, 6, 119.
5. Lea, F. M., *J. Inst. Civil Eng.*, 1936-7, 278.

SOME THEORETICAL AND APPLIED ASPECTS OF THE PHYSIOLOGY OF UNSTRIATED MUSCLE*

COMPARATIVELY speaking, more attention has been devoted by physiologists to striated than to unstriated muscle, though the disorders of former muscles are rarer. We are ushered into this world by the contraction of unstriated muscle, and disorders of the unstriated muscle of the alimentary canal and other tubular structures are common ailments. The modern stress and strain of life leads to the contraction of the unstriated muscle of the blood vessels, which in turn damages the kidneys and the heart, so that the problem of heart disease in coronary attacks is really the problem of blood vessels and their smooth muscle. Similarly, some disorders of the nervous system are due to vascular spasm, local and general.

CHEMICAL COMPOSITION OF UNSTRIATED MUSCLE

Interest in this subject has increased in recent years owing to its relation to hypertension. It is now generally recognised that ionic imbalance results in hypertension. Sodium causes contraction of the contractile mechanism by direct effect on its proteins. Retention of sodium would therefore result in hypertension. Intracellular potassium, besides being a suitable medium for the actomyosin system of the muscle, also maintains the normal excitability.

Potassium has a relaxing effect on the contractile mechanism of unstriated muscle, so that the fall of blood pressure due to retention of potassium is likely to be due to this effect. Intracellular calcium would be responsible for accommodation or adaptation of muscle. Calcium also causes contraction of the contractile mechanism. As there is a natural increase of lime salts in the arteries of the aged, the action of calcium might be responsible for the physiological increase of blood pressure with age. Calcium also causes extrusion of sodium.

EXCITABILITY

Unstriated muscle can be stimulated both electrically and chemically but in some unstriated muscles the properties of these two types of responses differ whether they be inhibitory or excitatory. In these muscles, therefore, it is possible to decide whether a particular response has been produced by electric current or a chemical substance. The application of this finding can be used to decide between the electrical and chemical theory of nerve transmission in certain situations. It is possible to say, therefore, whether a particular response has been produced by the action potentials of the nerve or by some humoral substance secreted by it. Experiments on the nerve-smooth muscle preparation of dog's and frog's stomach suggest that the action of the vagus nerve is produced by secretion of acetylcholine and

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not by the action potential of the nerve, as the response produced by nervous stimulation resembles that produced by a chemical substance.

The effect of various ions on unstriated muscle is well known. A somewhat different behaviour of some unstriated muscles is their ability to preserve their excitability in the absence of sodium, or even all electrolytes. Overton found that frog's striated muscle becomes inexcitable in a few minutes if it is immersed in an isotonic solution of sucrose. Frog's stomach muscle does likewise, but if the osmotic pressure of the sucrose solution is reduced by 30% to 40% (0.112 M), then after an initial depression the muscle recovers and remains irritable for several hours.

When the muscle is contracting strongly, chemical analyses show that it does not contain any significant amount of sodium. This is contrary to the action of sodium in nerve, but as the nature of excitability in general ought to be the same in all tissues, these experiments appear not to support the ionic hypothesis.

Action potentials can be reached from the muscle in hypotonic sucrose solution. This shows that no electrolyte is necessary in the external medium for the production of these potentials.

ACTION OF CHOLESTEROL

Cholesterol is deposited in the intima of the blood vessels in atheroma. The muscular coat may also contain it in excessive amounts, as there is no likelihood of any diffusion barrier between the intima and the other coats of the blood vessels. The question arises whether cholesterol acts as an inert substance, or whether it can cause tonic contraction of the arterioles. Cholesterol appears to cause constriction of blood vessels. This finding is of importance, as it would explain coronary attacks in the absence of sufficient atheromatous changes if there is hypercholesterolaemia. It would also explain the incidence of coronary attacks which occur after a meal. After a meal, there may be a rise in the lipoid, hence the cholesterol content of blood, and this may precipitate an attack.

METABOLISM OF UNSTRIATED MUSCLE

Metabolism in unstriated muscle usually follows the pattern found in striated muscle, but there are important exceptions. Unstriated muscle shows two types of contractions. One kind of response is accompanied by increase and the other by decrease in lactic acid production. The oxygen consumption also shows similar variations. Corresponding to this there

are two kinds of relaxations, one being followed by increase and the other by a decrease in the production of lactic acid or oxygen consumption. It is clear, therefore, that we are dealing with two contractile systems in this muscle, in one the relaxation being active and in the other, passive. These two kinds of relaxation can be differentiated by the action of substances which suppress metabolism. Thus sodium cyanide, iodoacetic acid, sodium azide, decrease active relaxation but increase passive relaxation.

ANTAGONISM BETWEEN ACTIVE AND PASSIVE RELAXATION OF MUSCLE

These two kinds of relaxation are antagonistic. This is shown by the fact, that in certain solutions, the muscle relaxes more if unloaded, than if it is loaded. This is due both to the excitatory and the contractile mechanism as it is also shown by muscle in which the excitatory mechanism has been destroyed by heating.

The existence of the two systems in some unstriated muscle can be shown directly. Thus, if the unloaded heat-killed muscle is heated to 60-70° C., then it relaxes. The supply of energy to the contractile mechanism thus causes active relaxation. If once the muscle is heated to 70° C., then active relaxation is permanently inactivated. It now gives a contraction which is proportional to rise in temperature, and the relaxation is passive. The supply of energy to the contractile mechanism, therefore, now causes proportionate contraction. In some muscles, therefore, both contraction and relaxation are energised.

RELATION BETWEEN MUSCULAR CONTRACTION AND DENATURATION OF PROTEINS

Denaturation of protein is supposed to consist of an alteration of the specific internal structure of the protein wherein the closely folded peptide chains unfold. Similarly, the contraction of muscle is supposed to be due to folding of the contractile protein; thus, relaxation would be due to the unfolding of the muscle proteins and the process of relaxation of muscle would be similar to the denaturation of proteins. The similarity between the two processes is shown by the fact that many agencies, both physical and chemical, which denature proteins also cause active relaxation of heat-killed unstriated muscle.

In the mechanism of enzymatic hydrolysis, it is presumed that the proteolytic enzyme at first denatures the protein. This action of the enzyme can be tested on the heat-killed un-