solution containing glycerol (400, 800, or 1200 mmole/liter) the muscle was returned to Ringer solution (*4*). This treatment markedly reduced the number of muscle fibers which exhibited oscillatory activity during subsequent application of caffeine, and oscillations disappeared within 20 minutes. Treatment with the highest concentrations of glycerol caused the most marked loss of oscillatory response to caffeine, but the response was never completely inhibited.

4) Previous treatment of the muscle with tetrodotoxin (10^{-7} g/ml) or *d*-tubocurarine (5 mg/liter) sufficient to block neuromuscular transmission did not inhibit the oscillogenic action of subsequently added caffeine. Treatment of a muscle with 3.7 m*M* procaine prevented subsequently applied caffeine from producing oscillations. This action of procaine was rapidly reversed when the anesthetic was washed out of the muscle.

5) Muscles soaked 1 hour in calcium-free Ringer solution containing 4 m*M* ethylenediaminetetraacetate exhibited oscillatory activity when caffeine was added to the bathing solution, but these oscillations disappeared in 2 hours. For a muscle treated for 24 hours in such a Ringer solution, the caffeine-induced oscillations endured only 6 minutes.

6) We have confirmed that 0.25 to 2.0 m*M* caffeine does not produce change in the resting potential of muscle fibers (*5*). Also, the drug does not appreciably alter the rate of rise or the amplitude of the action potential, but produces some slowing in the rate of repolarization (*6*). In a caffeine-bathed muscle, sarcomeric oscillations were observed in fibers in which the resting potential was normal. Muscle fibers whose membrane potentials were reduced to −30 mv or less, by application of increased concentrations of extracellular K^+, showed oscillatory activity when caffeine was added to the bathing solution. In caffeine-treated muscle fibers whose sarcomeres were quiescent, oscillatory activity could sometimes be initiated, with a latency of several seconds or more, when the membrane potential was reduced, by applied electric current, to values near the mechanical threshold (range −60 to −70 mv). Electrical hyperpolarization of a fiber decreased and sometimes stopped sarcomeric oscillations with a latency of a few seconds. In other experiments, oscillatory activity was initiated by application of 0.2 m*M* amyltrimethylammonium. Unlike caffeine, this drug caused rapid reduction of the postjunctional (and therefore extrajunctional) membrane potential to values approaching −50 mv. Thereafter the membrane potential rose to the control value, but despite such repolarization, oscillatory activity persisted throughout.

7) Sarcomeric oscillations were also produced at the region of the neuromuscular junction after application of 0.2 to 0.5 m*M* hexamethonium, 0.27 m*M* carbamylcholine, and several other quaternary ammonium compounds. Oscillatory activity has also been produced by other agents, some of which are structurally related to caffeine (*3*).

We propose that the oscillatory changes in the pattern of striations, as seen with the light microscope, probably are produced by transient asynchronous activation of individual myofibrilar bundles of which each sarcomere is composed. We further assume that groups of myofibrils which make up a sarcomere can be activated synchronously and thereby produce optical and mechanical changes (*7*). Regional activation of contractile elements by local increase in concentration of Ca^{2+} can be most simply accounted for if caffeine and other oscillogenic agents act directly on the sarcoplasmic reticulum and liberate the required Ca^{2+} at individual loci. Alternatively, in caffeine-treated fibers, the overall intracellular Ca^{2+} concentration may increase progressively to the point at which random activation of contractile elements occurs at an increased number of sites. In addition to the above mechanism, agents such as caffeine may act on the transverse tubular membrane at its zones of contact with the lateral sacs of the sarcoplasmic reticulum. At these regions caffeine might cause local oscillations of membrane potential sufficient to initiate Ca^{2+} release.

The generation of sarcomeric oscillations appears to be sensitive to sarcomere length, and the adenosine triphosphatase activity of the activated contractile elements may be stretch-sensitive. Such a mechanism has been suggested for insect flight muscle (*8*), and caffeine-treated muscle fibers may behave in a somewhat similar manner. Stretch-sensitive adenosine triphosphatase activity could help to explain both the oscillations of individual sarcomeres and the more extensive peristaltic-like waves of mechanical activity which we have observed. We propose that stretch-sensitive adenosine triphosphatase activity of contractile elements may be exhibited by normal vertebrate skeletal muscle during the "active state" and that certain important characteristics of the contractile system of skeletal muscle may depend on this property.

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Mosaic Unit Ruler: Does One Exist?

Abstract. *Ancient mosaic patterns tend to be certain absolute sizes (mosaic units). There is evidence that the mosaicists had these lengths marked on rulers. A ruler such as one which an ancient mosaicist might have used has been reconstructed. It is possible that an original may still exist.*

It has been reported (*1*) that geometric patterns in ancient Greek and Roman floor mosaics tend to fall into size groups, and that almost every pattern of a size group has one dimension of (virtually) the same length. Various evidence has been given (*1*) indicating that the ancients probably fixed this length by measurement, thus causing the size-group phenomenon.

Measuring more than 310,000 of these lengths produced the result (*2*) that only 0.6 percent are equivalent to known standard units of length, whereas 89 percent lie (*1*) within ± 3 standard deviations ($\sigma \cong 0.13$ cm) of the following values (mid-interval value of mode, class interval 0.1 cm): 1.2, 2.4, 3.6, 6.0, 9.6, 15.6, 21.6, 25.1, 40.7, 65.8, and 106.5 cm.

That these 11 values (mosaic units) are no accident is indicated as follows.

1) With the exception of 21.6 cm, mosaic units lie in a distinct series, each being the sum of the preceding two (within 0.1 cm).

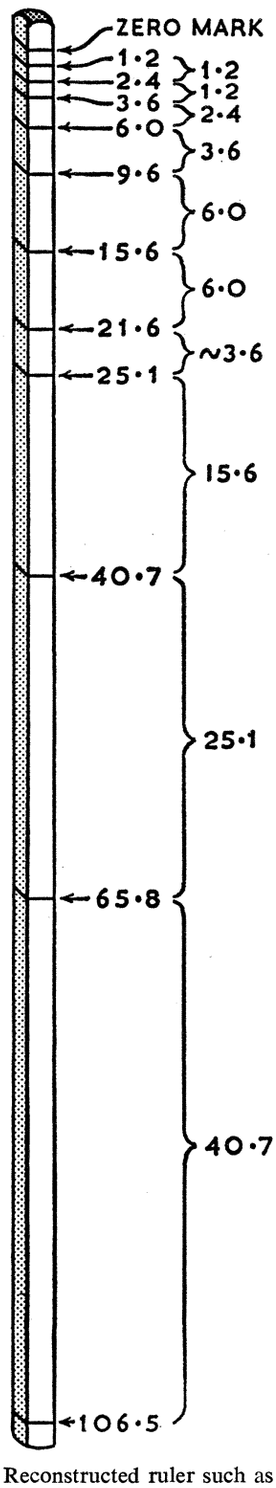

Fig. 1. Reconstructed ruler such as ancient mosaicists might have used. All lengths in centimeters. Measuring between each pair of calibrations, as opposed to measuring from the zero mark to each calibration, does not yield any extra values.

2) The typical dimensions of patterns greater than 106.5 cm have been successfully predicted (*2*) within 0.3 cm by extrapolating this series. But, substituting integers 1, 2, 3, . . . 14 for x, I find the relation

$$y = 1.197 \times \left[\frac{1}{\sqrt{5}}\left(\frac{1+\sqrt{5}}{2}\right)^x - \frac{1}{\sqrt{5}}\left(\frac{1-\sqrt{5}}{2}\right)^x\right] \text{cm}$$

yields a set of values for y which fit the observed mid-interval modal values ($c = 0.1$ cm) up to, and beyond, 106.5 cm within 0.07 cm (ignoring 21.6 cm).

3) Mosaic units (including 21.6 cm) lie within the ± 0.25 cm range of each value in a set of 11, experimentally shown (*3*) to be the most efficient pattern sizes in terms of stone packing.

4) Mosaic units (including 21.6 cm) lie within ± 0.1 cm of each of the 11 most efficient pattern sizes (*4*) predicted by a theoretical study of varied-particle packing.

I can find no likely relation between any of the lengths of 6646 different integral numbers and fractions of 89 pertinent known ancient standard units of length and the 11 mosaic units.

The only known ancient accounts of floor mosaic construction are apparently (*5*) those of Vitruvius, and of Pliny (who largely echoes Vitruvius). The Vitruvian sources state (*6*) that floor mosaics were ". . . *ad regulam . . . exacta . . . struantur . . .*" (that is, accurately formed by ruler).

Presumably this ruler was scaled in the 11 mosaic units. If it was like the ancient rulers still in existence (*7*), it would be a wooden stick of square section, with transverse cuts for calibrations. A reconstructed mosaic unit ruler is shown in Fig. 1.

I hope to draw the attention of those who possess ancient rulers to the possibility that an original mosaic unit ruler might have come down to us.

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6. For example, British Museum Harleian MS 2767, p. 95^{vesro}.
7. For example, Roman-Egyptian cubit ruler, Petrie Collection 1935-459, Science Museum, London.

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Immunological Response of Male Cockroaches to Injection of Tetrahymena pyriformis

Abstract. *After injection of living tetrahymena into the hemocoels of male cockroaches, recovered hemolymph immobilizes washed ciliates. The immobilizing material is sensitive to heat and acid, and can be separated with ammonium sulfate. Hemolymph from immune animals confers protection in another animal into which it is injected. Immobilizing activity of the hemolymph from immune animals is associated with a nonreactive, normal protein component present in hemolymph from nonimmunized insects.*

Several species of the ciliated protozoan *Tetrahymena* are natural facultative parasites in invertebrate hosts (*1*). In addition, several strains of usually free-living organisms of this genus may be experimentally introduced into various host organisms and tissues (*2*). The free-living S strain of *T. pyriformis* will live in the hemocoel of adult female American cockroaches (*Periplaneta americana*); the ciliates are easily recovered and isolated into axenic culture, and their morphological (*3*) and

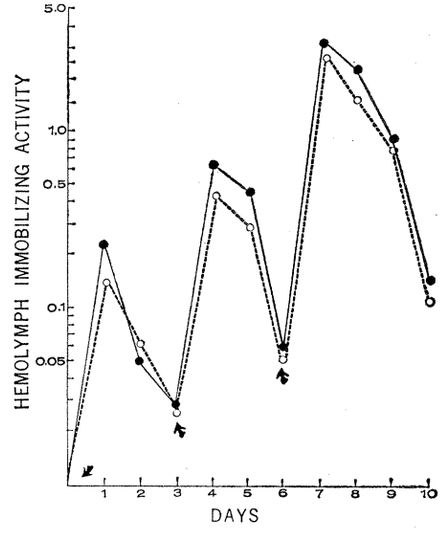

Fig. 1. Titer of immobilizing activity of cockroach hemolymph after repeated injections of *Tetrahymena pyriformis* S. Units of activity are expressed as the reciprocal of the minimum amount of hemolymph protein (micrograms) which in the standard assay effects immobilization of washed ciliates (see text). Arrows indicate time of injection of 250 μg (dry weight) of ciliates. Each assay was made in pooled diluted hemolymph from three animals. Closed circles and solid line represent data obtained upon injection of living ciliates; open circles and dotted line represent data with heat-killed ciliates.