times and three 3 times (on consecutive days). In 4 of these lesions have developed gradually and in one of these the uninoculated eye has become affected. In neither series was protection afforded by the vaccine, since more were affected in the vaccinated than in the unvaccinated groups. Regarding the gross appearance of the lesions there was no great difference. The condition was rather less active in the "direct transfer" series than in the "culture" series. The results obtained indicate that the condition induced by direct transfer from trachoma in Missouri was less easily transmissible than that induced by inoculation of cultures of *Bact. granulosis*. Quoting from the report "Whether this difference is significant and whether it would constantly be true can not be said without further tests." It may be that as in other diseases certain strains of the organism concerned may be more virulent than others.

The results reported by Olitsky, Syverton and Tyler in SCIENCE, for January 6, 1933,[4] lend support to the view that *Bact. granulosis* is concerned in the etiology of trachoma. Of significance is the use of tarsectomized tissue in the experimental work carried out by these investigators. The chances for successful transmission of the condition to animals and for isolation of the organism concerned are without doubt greatly enhanced by the use of large amounts of material. The great amount of negative evidence in certain localities as reported in the literature and in unpublished work concerning which information has been received by the writer, may possibly be explained on this basis. It is apparent that most workers have not used tarsectomized tissue, which is difficult to obtain because many ophthalmologists consider the tarsectomy operation as of questionable value for the cure of trachoma.

Another phase of the problem is of interest. If the work of Olitsky and collaborators can be confirmed in certain other parts of the world where only negative results have been reported, using the sort of material and the methods employed by them and it is definitely established that *Bact. granulosis* is the etiological factor in trachoma, then the isolation of an organism which is non-filtrable and which grows on the ordinary culture media, from a disease which is characterized by the presence of inclusion bodies, takes on a certain significance. A revision of the rather generally accepted view of the nature of the infective agent in at least some of the group of diseases in which inclusion bodies occur (diseases usually classified as belonging in the "filtrable virus" group) would be necessary. As I reported in 1928[5] in a study of inclusion bodies in over 200 cases of trachoma these bodies were present in nearly 50 per cent. of the cases. More recently, Taborisky[6] has reported that observations during a period of 20 years justify the belief that there can be no trachoma without inclusion bodies at some period, if cases are followed from the beginning. As the result of the microscopical study I reported that the inclusion body in the early stages was composed of rod-shaped organisms. A photograph of a very unusual preparation is shown in this publication, in which the nucleus of an epithelial cell is surrounded by numerous rod-shaped organisms which morphologically at least could very well be said to correspond with *Bact. granulosis*, though identification on this basis is obviously impossible. The definite rod-shaped forms are seen very rarely. Usually the inclusion body appears as a more or less structureless mass, in which at a later stage very minute coccoid bodies staining reddish with Giemsa appear. Apparently the group of organisms forming the inclusion body is acted on by the living cytoplasm of the epithelial cell and transformed into these small bodies which are the "elementary bodies" of Halberstaedter and von Prowazek. These are visible when occurring in the cell, but it may be that they occur outside the cells also, in which case they are indistinguishable or very nearly so. The difficulty of cultivating such forms can be readily understood. As stated in an article now in press, these "elementary bodies" are probably for the most part non-cultivable and they may constitute the active infectious agent, the so-called "virus," while the rod forms which are cultivable occur only rarely. In a word the organism when developing in the tissues may occur in a different form than when growing on artificial culture media. The supposition offers an explanation of the difficulty of cultivating the organism unless large amounts of material are used, in which the chances of encountering the definite rod forms are increased.

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THE ACTION-CURRENT AS MEASURE OF MUSCLE CONTRACTION

IT has been considered impossible to show a definite quantitative variation of the action-current with the contraction of human muscle. Upon contraction the oscillations of the oscillographic curve, which are always running even with resting muscle, coarsen and widen, but it is impossible to correlate changes of frequency or changes of amplitude with the degree of contraction, for the good reason that the oscillations during the contraction have no definite frequency and no definite amplitude; detailed study of the curve

[4] P. K. Olitsky, J. T. Syverton and J. R. Tyler, SCIENCE, 77: 24, January 6, 1933.

[5] Ida A. Bengtson, *Pub. Health Rep.*, 43: 2210, 1928; *Amer. Jour. Ophth.*, 12: 637, 1929.

[6] J. Taborisky, *Graefe's Arch. f. Ophth.*, 124: 453, 1930.

shows that the oscillations are extremely irregular. A significant measure of the action-current during contraction must be in terms of a summation of the current.

The planimeter measure of the area generated by the oscillographic curve during the contraction-disturbance is possible; but the method is tedious and inaccurate. But the summation of the action-current disturbances by a ballistic galvanometer is convenient and accurate; the action-currents have only to be amplified without distortion, rectified and photographically recorded.

An adequate method of measuring the action-currents from the muscle contraction is the less difficult part of the problem. There must also be some measure of the force of the contracting muscle. The group of muscle fibers must be isolated so that the contraction has a definite beginning and end in time; and the force that they exert must be measured in terms of some simple physical result. If the contraction is opposed by antagonistic muscles excess heat will be developed which it is impossible to measure.

The type of movement known as "ballistic," and familiar in many forms of skilled movement, like piano-playing and typing, can be made to fill these conditions. In the free (or "loose") movement of a skilled pianist, the flexor group actuates the forearm by a sudden pulse which has a uniform duration of about 45 sig.; it is quite unopposed by the extensors and sets the limb in motion with a very rapid acceleration, whereafter for three fourths of the stroke the limb swings free by momentum with a uniform velocity which is easily measurable; under proper conditions the length of the stroke varies with the velocity. It is easy to check such movements from the kymograph tracing; during the momentum phase the tracing is a right line which can easily be tested with a straight-edge; in a series of such strokes the ratio of the velocity to the length of stroke is fixed if they are ballistic. A skilled pianist can make such free and ballistic movements eight out of ten times.

Since the mass of the moving limb is constant and the path of the excursion can be made constant, the velocity of the ballistic movements becomes a measure of the varying force of the contractions. For the success of the study we found the choice of skilled pianists as subjects a vital point. The upper-arm was fixated so that the elbow joint was maintained in the same position to make the path of the excursion constant. The forearm was carefully supported so that a free, horizontal movement could be repeated without any influence of gravity, and the movements were recorded on a kymograph.

Electrodes of Ag or Zn shaped to fit the surface, wrapped in muslin wet with NaCl solution, were bound firmly with adhesive tape to the arm over the respective muscles. Under these conditions a series of movements were recorded and the corresponding contractions were registered from the ballistic galvanometer.

An actual series of strokes gave the ratios of excursion to velocity: .28, .26, .31, .31, *.23*, *.24*, .31, .28, *.35*, .26, .32. It is apparent that the fifth, sixth and tenth strokes are not free; and a check of the kymograph tracing with straight-edge confirms this. If the summated action-currents vary with the velocity, the ratio of velocity to action current should be fixed; the actual values in this case were: 1.0, 1.2, 1.1, 1.2, *1.7*, *2.0*, 1.4, 1.2, *0.9*, 1.1, 1.1. With the exception of the tense strokes, fifth, sixth, tenth, the values vary within 10 per cent., which is significant in physiological measurement.

When movements of this type occur against a fixed external tension, it was found possible to fit the results to an equation in which a constant (a) multiplied by the excursion plus a constant (b) is equal to the action-current (a Exc. + b = Ac. cur.). This indicates that a constant number of fibers is employed in overcoming the fixed resistance.

If a to-and-fro movement of this form is repeated in series in which both the beat-stroke and back-stroke are ballistic, the results are much more precise. A series of 25 movements with 3-inch excursion, a series of 25 with 5-inch excursion and a series of 25 with 7-inch excursion, all over the same path and at the same rate per sec., were recorded on the kymograph. In such series all the force exerted by the contraction of the flexor group of fibers and of the extensor group of fibers appears in the momentum of the to-and-fro movements; and the momentum varies directly with the length of excursion.

Parallel records were made by a ballistic galvanometer of the summated action-currents of the flexors and by a second ballistic galvanometer of the summated action-currents of the extensors. The sum of the summated flexor- and extensor-action-currents should be proportional to the length of excursion of the respective series of movements (which is an indicator of the force exerted). Thus in an actual case, the readings show a series of 2-in. excursion with a ratio to the sum of the action-currents of .86, and a series of 5-in. with a ratio of .86, and a series of 7-in. with a ratio of .83. When repeated in reverse order, the series give ratios: .83, .86, .85.

It is easy to make an ocular demonstration of this quantitative relation between action-current and muscle contraction by sending the amplified, rectified action-currents from rapid to-and-fro movements through a milliameter or a level indicator; the oscillating pointer will indicate a middle point for the series of contractions from a series of horizontal ballistic movements. The one important thing is to have a skilled pianist as subject capable of making the free ballistic movements. If the rate per sec. of the movements, as well as the path, is fixed, it is easy to see the shift of this middle point of oscillation of the indicator pointer with each change in length of excursion of the movement series, and approximate readings may be made to show the proportionality.

If the subject increases the rate per sec. of such a series of ballistic movements, the readings of the level indicator show some interesting relations. As the subject approaches his maximum rate, the amount of action-current indicated reaches a maximum; apparently the muscles are exerting their maximum force; from that stage on the increase in rate per sec. reduces the excursion proportionally. The maximum rate per sec. is achieved with the minimum excursion; in the final stage the excursion is very slight and the coordination is irregular and a "forced tremor" supervenes.

It is evident that there is a maximum number of available fibers for a given movement and when that number is in action the increase of rate of the repeated movement depends on reducing the excursion so that the flexor and extensor groups of fibers can each take up the momentum in reversing the movement of the limb; at last the coordination breaks down, the movements are irregular and a forced tremor is the result.

These results were obtained repeatedly with some four subjects. The maximum rate differs somewhat from subject to subject, but there are no essential differences in the quantitative relations of action-current and contraction. It is obvious that the findings fit the all-or-none hypothesis for the contraction of human muscle fibers.

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CHEMICAL VERSUS MORPHOLOGICAL SPECIES DIFFERENCES

THE writer has had the opportunity to make analyses of the sap of plants of the genus *Valonia* from many localities. Under current classification based upon morphology, these plants are referable to three or four different species. But, as has already been pointed out in the case of plants classed as *Halicystis ovalis* (Lyng.) Areschoug, chemical differences contravene morphological characteristics.[1] These chemical distinctions have since been utilized in segregating part of the genus *Halicystis* as a new species.[2]

Table I shows the relevant data in the case of genus *Valonia*. The new analyses in this table were made by the following methods: Halide was determined by titration with silver nitrate; it consists predominantly of chloride. K + Na was determined as total sulfate, K as chlorplatinate and Na by dif-

TABLE I
CHEMICAL CHARACTERISTICS AND ENVIRONMENTAL DATA FOR VARIOUS REPUTED SPECIES OF VALONIA

Reputed species	Locality	Habitat	Depth	Water temperatures*	Composition of sap				Condition of materials	Authority (See footnotes)
					K	Na	Cl	K/Na		
			m	°C.						
Valonia utricularis	Naples	On rocks	0	?	368	20.4	369	(18.0)	= –	4
	"	" "	0	?	291	152	418	1.91	= –	5
	"	" "	0	18°	372	266	639	1.43	Fair (March)	–
V. macrophysa	Naples	On tunicates	30	12°	465	164	657	2.77	Good (February)	–
	Dry Tortugas, Fla.	On masonry	0	28°	494	97	617	5.10	Good (June)	6
	Bermuda	On coral rocks	0	25°	517	90	597	5.73	–	7
V. ventricosa	Makahaa, Tonga	Under rocks	0.3	25°	497	125	619	3.97	Excellent (Sept.)	–
	Main shore, Tonga	On sea weeds	1.0	25°	545	55	620	9.92	" "	–
	Dry Tortugas, Fla.	Under rocks	0.3	28°	562	46	618	12.21	" (June)	–

* Water temperatures are only rough approximations.
+ Mean of four controls.

[1] S. C. Brooks, *Proc. Soc. Exp. Biol. Med.*, 27: 409–12, 1930.

[2] L. R. Blinks and A. H. Blinks, *Bull. Torrey Bot. Club*, 57: 389–95, 1930.

[3] A. Meyer, *Ber. Deutsche Bot. Ges.*, 9: 77–9, 1891.

[4] S. Camlong and L. Genevois, *Bull. Sta. Biol. Arcachon.*, 27: 309–21, 1930.

[5] E. Pantanelli, *Bull. Orto Bot. R. Univ. Napoli*, 6: 1–37, 1918.

[6] S. C. Brooks, *Protoplasma*, 8: 389–412, 1929.

[7] W. J. V. Osterhout, *Jour. Gen. Physiol.*, 5: 225–30, 1922.