Physiology. — *Muscle sounds of a single twitch.* By G. VAN RIJNBERK and H. D. BOUMAN.

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Introduction.

HERROUN and YEO have described for the first time that a single twitch produces a muscle sound (1885). They stimulated the muscles of the upper arm with single shocs and listened with a stethoscope.

With stimuli strong enough to give a clearly visible twitch, a low sound was heart comparable to the first heart sound.

BERNSTEIN in 1890 found (also in listening experiments) that a single shoc given to the gastrocnemic of the rabit produces a muscle sound. It was of an explosive caracter comparable to *p* or *t*, or the sound of lighting a gas lamp. The frequency could not well be determined because of the extreme shortness of the sound.

I. *Experiments on dogs muscles.*

Our experiments were performed on dogs. Motor nerves were stimulated with single condenser discharges. The sound has been recorded by the same technique that has been used in our experiments on voluntary contractions in man. Dog and experimenter are enclosed in the sound proof room of the laboratory, the amplifier and recording string oscillograph are outside this room.

We have used the gastrocnemic and some segments of the rectus abdominis muscle. In all experiments a muscle sound has been found. Experiments have been performed with the nerve intact and with the nerve cut. The results in both cases shows no differences. In some experiments the muscle (gastrocnemic) was left completely in situ, in other experiments the tendon has been cut and the muscle freed from its surroundings and placed on cotton wool. (The blood supply was not damaged by the operation.) The reason for this was the following. In some experiments on muscles in situ we were struck by the extreme regularity of the records, a regularity which was completely unknown in our previous records of voluntary contractions in man. The records had the caracter of being due to the tapping of some structure which can easily be set in vibration. The records in fact is those of an aftervibration. The question arose whether this vibrating structure is the muscle itself or the underlying bone.

The answer to this question is obvious from two records reproduced here. One is from a muscle in situ while the other is from a muscle isolated as much as possible from the bone but with the blood supply undamaged. The muscle was placed on cotton wool.

The difference between the curves is clear. The vibrational caracter has entirely disappeared by the isolation of the muscle. Therefore these experiments are the first records of the true muscle sound of a twitch, HERROUN an YEO's and BERNSTEIN's results have been due to the under-

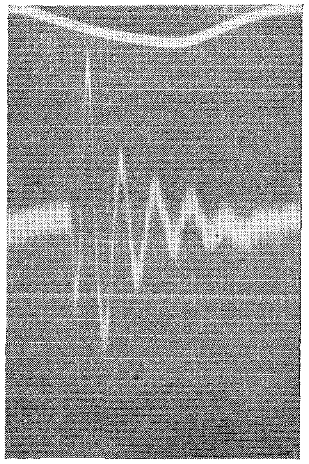

Fig. 1. Rec. E 20.
Muscle sound of a twitch
Muscle in situ.

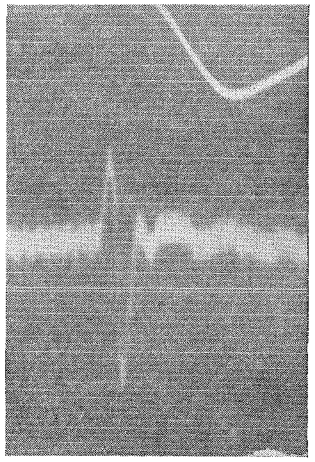

Fig. 2. Rec. E 82.
Muscle sound of a twitch, muscle isolated with undamaged bloodsupply and placed on cottonwool.

lying bones. A sound as recorded in fig. 1 can doubtlessly give an aural impression as described by BERNSTEIN. The sound recorded in fig. 2 would sound entirely different, if at all audible.

In all experiments the main feature of the muscle sound is a single diphasic effect: the $\alpha\,\beta$ effect. In many curves this is followed by some

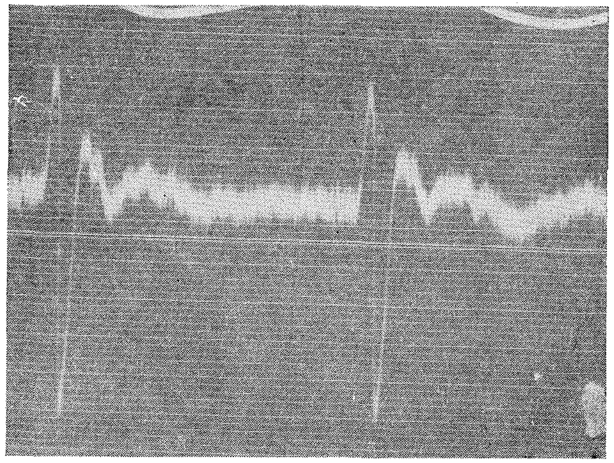

Fig. 3. Rec. 84.
The $\gamma\delta$ complex of the muscle sound of a single twitch of an isolated gastrocnemic.

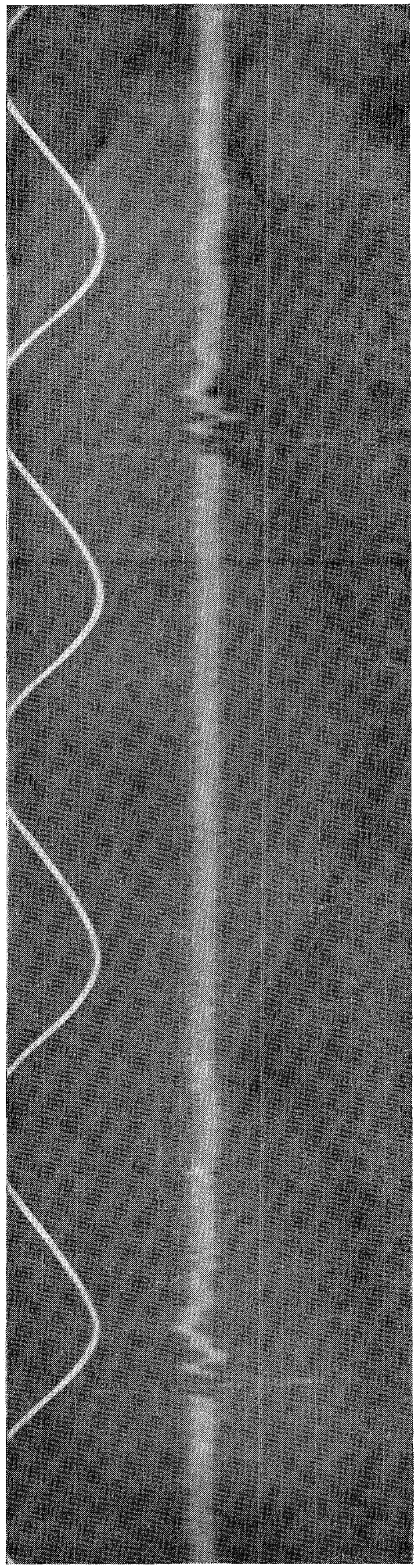

Fig. 4. Rec. 48. Freq. 4 per sec.

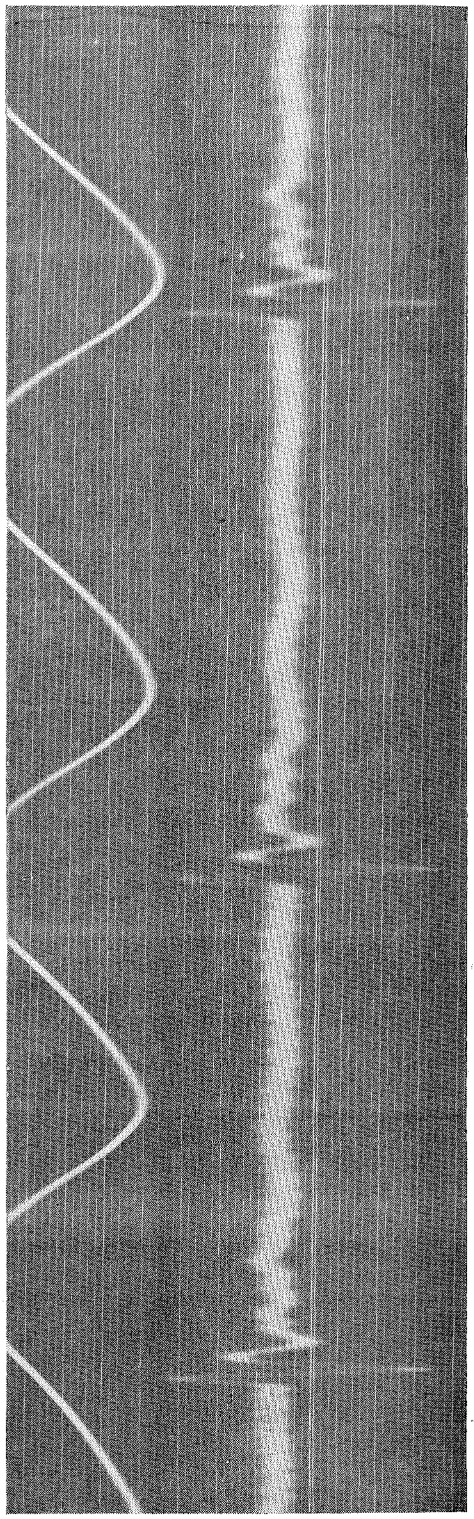

Fig. 5. Rec. 51. Freq. 8 per sec. Fig. 1—5 gastrocnemius. Time $^1/_{10}$ sec.

irregular vibrations of low amplitude, which are not comparable to after vibrations. In some records where they are exceptionally big they have been labelled $\gamma\,\delta$ complex (see fig. 3).

The curve does not change on cutting the motor nerve, the complex therefore cannot be described as a reflectory after discharge following the main twitch. As the nerve has always been stimulated close to the muscle, differences in conduction time of different nerve fibres cannot account for the after effect.

An increase in frequency of the stimuli gives little or no change in the recorded sounds. (See figs. 4 and 5.)

The phenomena recorded at higher frequencies when tetanic contraction sets in will be the subject of a seperate paper.

The experiments show therefore that a single twitch does produce a muscle sound. If the muscle is in situ above the underlying bone the caracter of the sound is determined mainly by the bone. It is comparable to after vibrations.

In an isolated muscle however the sound is much more simple. The main feature of the sound is a single diphasic vibration ($\alpha\,\beta$ complex) followed in many experiments by a second diphasic vibration of much smaller amplitude ($\gamma\,\delta$ complex). It is impossible to discuss the pitch of such a phenomenon.

We thought of finding a good muscle for these experiments in the rectus abdominis muscle of the dog. We thought it reasonable to suggest that if a middle segment of this muscle contracts, the surrounding segments will isolate it from its bony insertions (sternum, pelvis). The curve reproduced in fig. 6 shows that this is indeed possible.

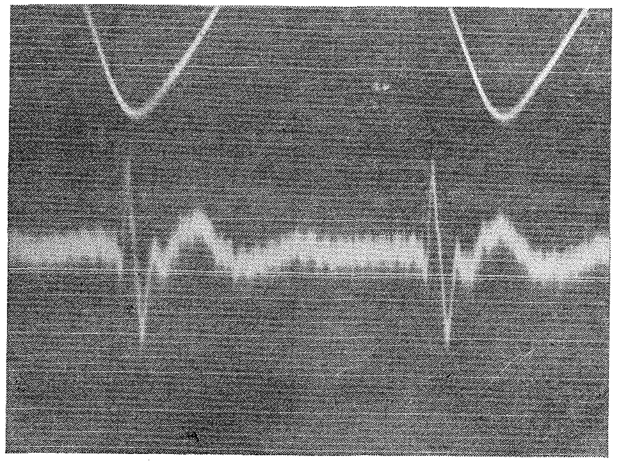

Fig. 6. Rec. 116.
Twitch of M3 of the rectus abdominis.

The necessity for great care however becomes obvious from a comparison of this record with the record reproduced in fig. 7. The contracting segment was situated one segment more caudad, and therefore closer to the pelvis.

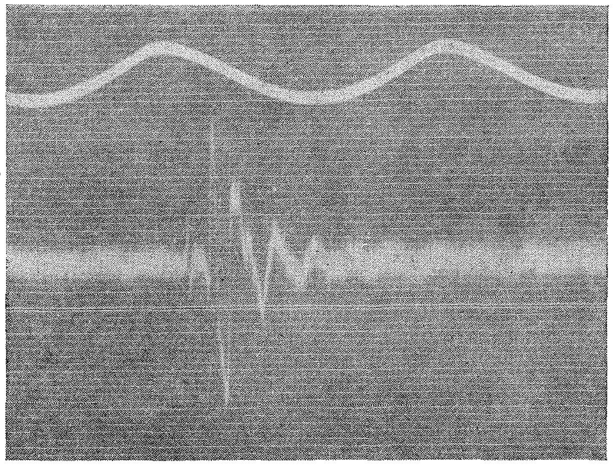

Fig. 7. Rec. 189.
Twitch of M4 rectus abdominis.

In this curve the regular vibrations of an after vibration can already be recognised.

The sharp excursion in this experiment preceding the complex is a signal which recorded the moment of the stimulus.

II. *Experiments on frogs.*

In order to verify the results obtained with dogs muscles, some experiments were performed on the more easily available gastrocnemic of the frog. Excised nerve muscle preparations have been used throughout.

A simple apparatus was constructed which enabled us to keep the muscle under any tension necessary and at the same time eliminated vibrations not due to the muscle itself. It consists of a heavy lead bloc. On one end a support was attached (also of lead) in which the femur could be clamped. A small lead carriage moving on ball bearings and provided with another clamp served to secure the tendon. For isotonic contractions a cord attached to the carriage could be loaded with different weights. For isometric contractions the carriage could be fastened to the supporting lead bloc.

Records of the acoustical phenomena of a single isometric twitch showed a constant picture, consisting in one single diphasic vibration. There is no after effect ($\gamma\ \delta$ complex). The results therefore appear to be in close agreement with those obtained on dog muscles.

Yet we do not expect to continue our experiments with frogs as the much stronger and bigger dog's muscles give much larger excursions in our records.

Conclusion.

The acoustic phenomenon of the muscle twitch suffers from serious interference from sounds produced by the bones if the muscle is stimulated in situ. The interference appears in the form of a common type of damped vibration. If the muscle is isolated from its bony insertions and placed on cotton wool (blood supply undamaged), records of a much simpler type are obtained.

The acoustical effect then consists of a single diphasic excursion (called $\alpha\ \beta$ complex) followed by another diphasic excursion of much smaller amplitude (called $\gamma\ \delta$ complex). Records obtained from frog's muscles are not essentially different from those obtained from dog's muscles.