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those two forms, i.e., the envelope of one system of osculating ellipses has 4 cusps, the envelope of the other has none.

Case 2 is to be considered as a combination of Fig. 9 and Fig. 10. a touches (C) in two points, b has two cusps on the line which connects O with the points of contact of a with (C). The dynamical problem allows of a single simple vibration.

Case 3 gives rise to a combination of Fig. 10 and Fig. 11 (or Fig. 12). There is *one* system of osculating ellipses.

Case 4 to a combination of Fig. 10 and Fig. 11 (or Fig. 12). There is *one* system of osculating ellipses. Moreover the dynamical problem allows of a simple vibration.

In the case $p < 0$ we have again in the first place envelopes corresponding in the main with those represented in the Fig. 14—20. We should, however, bear in mind, that in general the cusps do not disappear by 8 but by 4 at a time. There is for instance a transitional form possible between Fig. 18 and Fig. 19 in which 4 cusps occur, and in Fig. 14 and Fig. 15 4 cusps may have fallen out. In order to obtain the other forms of the envelope we must make use of the observation about (L') in § 7.

If the branch of (L) lying outside (C) touches (C) in two points, then the dynamical problem allows of *one* simple vibration. If (L) cuts (C) in 4 points, then we get one of the two domains of motion of Fig. 16, etc.

Is (K) an hyperbola or a degeneration then the various shapes of (L) may be deduced in the same way from the Fig. 3—6.

Physiology. — "*On the reflectorical influence of the thoracal autonomical nervous system on the rigor mortis in cold-blooded animals.*" [1]). By S. DE BOER. (Communicated by Prof. C. A. PEKELHARING.)

(Communicated in the meeting of January 31, 1914).

The rigor mortis that is caused by hardening and shortening of the muscles begins in warm- and cold-blooded animals after the circulation of the blood has stopped for some time, in warm-blooded ones 5—8 hours, in cold-blooded ones 1—2 days. If with a muscle that has been removed, we make provision for a sufficient supply of oxygen, it mortifies without stiffening. A special chemical state

[1]) According to experiments made in the physiological laboratory of the University of Amsterdam.

that is caused by a deficiency of oxygen, is consequently an indispensable condition for rigor mortis of the muscles, HERMANN showed moreover that the process of rigor mortis is accelerated from the central nervous system, whereas EWALD ascribed this accelerating influence to the labyrinth.

Last year I established, that, both for warm- and cold-blooded animals, the *tonus* of the skeleton-muscles is entertained by impulses reaching the muscles along the efferent, thoracal autonomical nerve-tracks [1]). I demonstrated this by the section of the Rami communicantes on one side, after which the muscles of the same side become atonic. In this way I could fully ascertain, by a physiological experiment, the double innervation established by BOEKE [2]) on account of morphological investigations, and, at the same time, I could establish the signification, which autonomic innervation has on the transversally striped muscles.

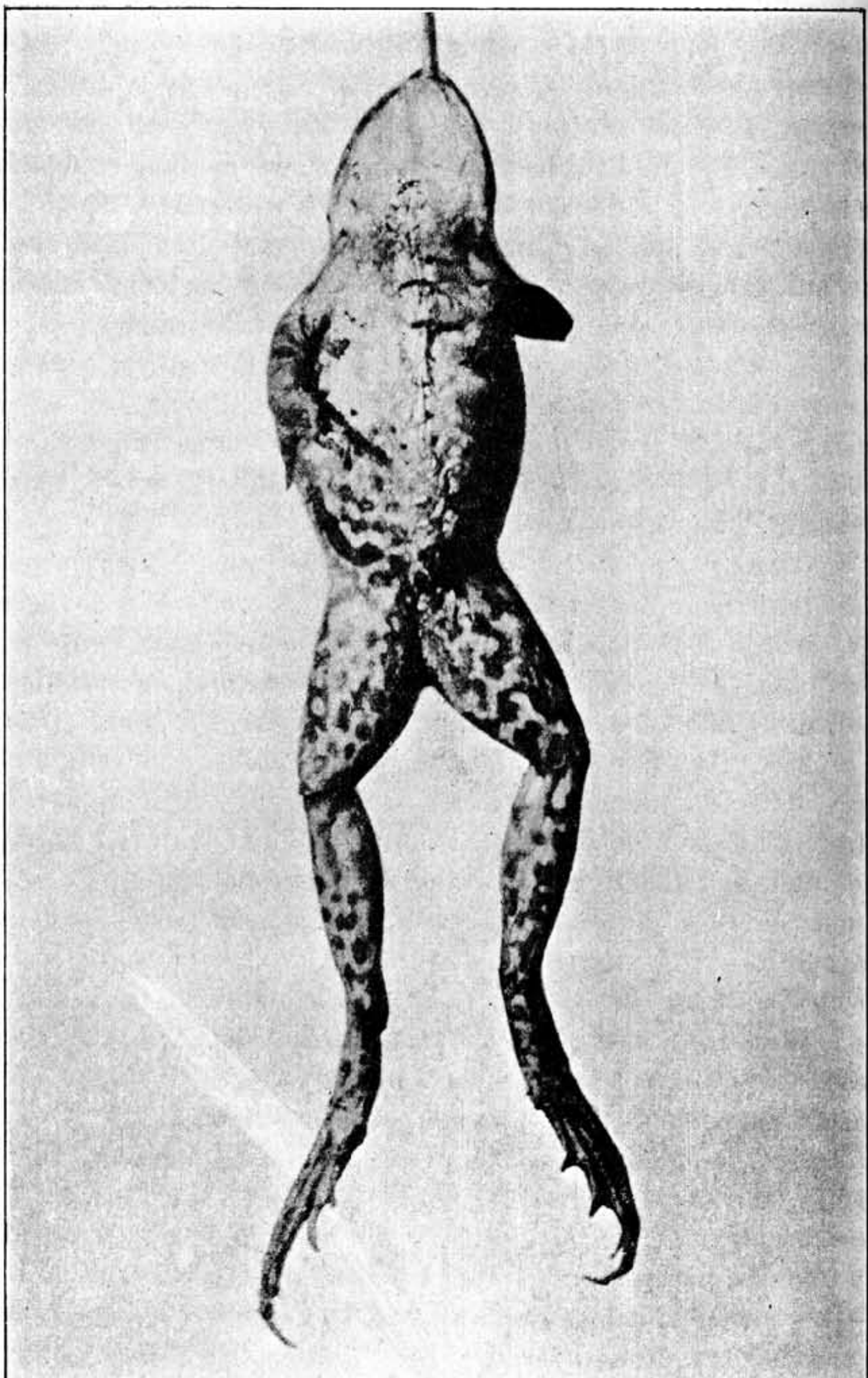
In the many operations that I made on frogs, I was struck by the fact that, after death, the hind-leg of the operated side was still supple, when the other hind-leg was already quite stiff. So on January the 13th I cut the right Rami communicantis and the sympathetic chain of a frog as high as possible. The next afternoon at 6 o'clock the frog was no longer very active. On the 15th of January I found it dead, all limbs were supple. Now I laid down the frog with both hind-legs flexed in the same way. At 4 o'clock of the afternoon the right fore- and hind-legs are still quite supple. The left hind-leg however is, both in hip- and knee-joint, stiff in flexed position with strengthened dorsalflexion in the foot-joint. The left shoulder- and elbow-joint are also stiffened. The axis of the body is flexed with the concave side to the left. These particulars can easily be observed in the photograph.

At half past five the condition is still unchanged.

At half past eight p. m. there is likewise a beginning of rigor mortis in the right hind-leg and in the right shoulder. At eleven o'clock the right fore- and hind-legs are also quite stiffened. On the 18th of January the rigor mortis has entirely ceased. This observation was made at a temperature of 17° Celsius. Consequently the rigor mortis began, on the side where the Rami communicantes had been cut, 7 hours later than on the other side, where the muscles were still connected with the spinalcord by means of the autonomic nerve-tracks. This observation induced me to a series of intentionally

[1]) Folio Neurobiologica VII (1913) 378 and 837.

[2]) Verslag der Wis.- en Natuurk. Afd. Kon. Akad. v. Wetensch. Amsterdam, April 1909. Deel XVII, p. 1008—1012.



Frog of which the right Rr. communicantes have been cut through in the beginning stage of rigor mortis. The left shoulder and elbow are stiffened, the left hind-leg is stiffened in flexed position both in hip- and knee-joint with strengthened dorsal-flexion of the foot. The axis of the body is bent with the concavity to the left.

The right fore- and hind-legs are still quite supple.

made experiments in which I removed, as much as possible, incalculable influences. I proceeded in the following manner:

A short time before I hung the frog in the damp case, or occasionally a few days previously, I cut, on the right side, the Rami communicantes and the right sympathetic chain at the top. By binding up the heart I killed the frog, then I passed a thread through the two jaws, and on these I hung the frog in a closed, glass-case that was kept damp by a wet sponge and by thoroughly wet filter-paper on the bottom. The damp case was then placed in a room in which the temperature was raised as high as 30° to 35° Celsius. The frog was consequently placed in regularly heated damp surroundings. By this higher temperature the process of rigor mortis is considerably shortened. It could easily be observed in these frogs, that the right hind-leg hung down suppler than the left one, that consequently the tonus had disappeared from the muscles at the right side.

A short extract from the protocols may follow here:

I. *17 January.* All Rami communicantes of the right side are cut.

20 January: After the heart has been bound up the frog is hung in the damp case.

4.30. Left hind-leg is drawn up, stiffness in hip, knee-joint and foot. The left elbow-joint is stiffened, no difference is to be observed in the two shoulder-joints.

Right elbow and whole right hind-leg are still supple.

5.30. Situation still the same.

9.30. The two hind-legs are hanging in stiffened tense and abduction position; the two fore-legs stiffened in flexed position.

22 January. Rigor mortis has ceased.

II. *21 January.* 1.15. The Rr. communicantes are cut through.

1.30. The heart is bound up. The frog is hung in the case.

5.30. Left shoulder-joint is stiff, other joints are still supple.

7.30. Situation unchanged.

8.30. Beginning of rigor mortis of the left hip.

9. Right shoulder begins to become stiff.

10. Left elbow stiffened.

11.30. Left knee begins to stiffen, the hip is quite stiff.

22 January. Stiffened tense and abduction position in all joints of the hind-legs.

23 January. 9 a. m. The rigor mortis has ceased.

III. *19 January.* 11.15 a. m. The Rr. communicantes are cut through.

11.30. The frog is hung in the case after the heart has been bound up.

4. p. m. Left fore-leg stiffened in the elbow- and shoulder-joints, left hind-leg is strongly flexed and stiffened in the hip, dorsal flexion and rigor mortis of the foot-joint.

4.30. Left knee is becoming stiff.

5. p. m. Right elbow-joint, knee and hip begin to become stiff.

6. p. m. Entire rigor mortis with abduced and tense hind-legs and expanded webs.

24 January. 12 a. m. The rigor mortis has ceased.

IV. *22 January.* 11.15. The Rr. communicantes are cut through.

11.30. The frog is hung in the case after the heart has been bound up.

5. p. m. Beginning of rigor mortis in left elbow and shoulder.

9.30 p m. Left fore-leg entirely stiffened, right one only in the shoulder-joint. Left hip and knee entirely stiffened in flexed position. Beginning of rigor mortis of right hip, right knee joint is still supple. Right foot is still supple, whilst the left one is entirely stiffened. The entire left hind-leg hangs with strong flexion in the hip tense foot and expanded webs. The right hind-leg hangs still in the usual slightly flexed position.

10.15. Situation unchanged.

11.30. The left hind-leg shows stiffened tense position, the right hip-joint entirely stiffened, beginning of rigor mortis in the right knee and foot. Temp. is 28° Celsius.

23 January 9 a. m. Both hind legs are hanging in completely stiffened tense and abduction position.

24 January. The rigor mortis has ceased.

V. *23 January.* 8.45 a. m. The Rr communicantes are cut through.

9 a. m. The frog is hung in the damp case after the heart has been bound up.

1 p. m. Left shoulder and hip show more resistance than right ones. Left hind-leg drawn up with strong dorsal flexion of the foot.

2 p. m. In left knee and foot more resistance than in right ones

3 p. m. The right hip becomes also stiffer.

4 p. m. The two hind-legs are hanging in tense and abduction position.

VI. *24 January.* 8 45 a. m. The Rr. communicantes are cut through.

9 a. m The frog is hung in the damp case.

12. Beginning of rigor mortis of left shoulder-joint.

4 p. m. Left hip shows more resistance than right one.

4 30. Left hind-leg stiffened, with strongly flexed hip, knee and foot

6 p. m. Left hind leg still in stiffened flexed position. The right one is still quite supple. Both the shoulder-joints are stiffened.

8.30. Beginning of rigor mortis in the right hip.

9.30. Right hip entirely stiff, the knee is still supple.

10.30. Right knee also entirely stiffened, the right foot is still supple.

26 January. 10 a. m. Both hind-legs are hanging in stiffened tense and abduction position.

26 January 5 p. m. The rigor mortis has ceased.

VII. *24 January.* 9.15. The Rr. communicantes are cut through.

10 a. m. Frog hung in the case after the heart has been bound up.

5.30. Left hind-leg more flexed in the hip and with greater dorsal flexion of the foot than right one.

6 30. When lifting the left hind-leg greater resistance than in the right one.

9.30. Stronger resistance in the left hip.

10.30. Left hip, knee and foot are still in flexed position, right hip beginning of rigor mortis; right knee and foot still quite supple.

26 January. Both hind-legs are hanging in stiffened extension- and abduction-position (25 Jan. not controlled).

26 January. 5 p.m. Rigor mortis has ceased.

VIII. *26 January.* 9.45. The Rr. communicantes are cut through.

10 a. m. Frog hung in the damp case, after the heart has been bound up.

1 p. m. All joints still supple.

6 p. m. Left shoulder and elbow stiffened, slight rigor mortis in left hip.

9 p. m. Left hind-leg completely stiffened in tense position with expanded webs.

Right shoulder and elbow also stiff, but less so than left ones. Right hip stiff in flexed-position, but right knee and foot are still supple.

So I have made a series of 20 experiments in which I always found retardation of rigor mortis on that side where I had cut through the Rr. communicantes. The process of rigor mortis is consequently accelerated, when the muscles are connected with the central nervous system by means of the efferent autonomic nerve-tracks. In the first operation, which was performed at roomtemperature the operated side stiffened at least 7 hours after the not operated one. But also in experiments that I made at a temperature of over 30° Celsius, the difference was even 1 or 2 hours. The experiments mentioned here were made on individuals of Rana esculenta. I made also some experiments on Rana temporaria, in which the process of rigor mortis went off quicker. In my opinion the reason of this is to be found in the much thinner limbs by which the relation between volume and surface of the muscles becomes less favourable. Hereby the mortification-process and the process of rigor mortis is evidently promoted. The same difference between the operated and the not operated side I observed here likewise. In all my experiments it struck me immediately that of the fore-legs the shoulder, and of the hind-legs the hip stiffens first. The knee however was now stiff before the foot, now the reverse took place. With slight deviations this occurred thus according to the law of NYSTEN.

Further in all my experiments the flexors stiffened first and afterwards the tensors. No exception was made in this respect for the hind-legs, so that at the end of each experiment the hind-legs were in a tense position. Further I must point out that in all my experiments the rigor mortis was accompanied by a shortening of the muscles, first rigor mortis and shortening of the flexors, then of the tensors.

HERMANN, who first proved that the process of rigor mortis was accelerated under the influence of the central nervous system, took rigor mortis for a last contraction of the muscles. Because, as I have just shown, rigor mortis is influenced by the central nervous system along the autonomic nerve tracks, as is likewise the case with the muscle-tonus, I am of opinion that rigor mortis is a last tonical muscle-shortening. This view is also entirely in keeping with PEKELHARING's [1]) investigations, who proved that the percentage of creatine of the muscles increases with rigor mortis, as is likewise the case with increased tonus.

Now the question arises: how is rigor mortis brought about? The usual explanation is, that through the mortification of the central nervous system the muscles receive stimulants along the nerve-tracks, and these stimulants accelerate rigor mortis. EWALD was of opinion that these stimulants originate in the labyrinth, whilst FLETCHER proved that supply of oxygen makes the muscles mortify without rigor mortis. I think I can now give a more general explanation, corresponding with the facts that are known.

We know that rigor mortis only begins, when the circulation of the blood has ceased. We obtain then in all tissues an accumulation of products of metabolism consequently suffocation. And now it is known that, if we kill an animal by hemorrhage or suffocate it by pinching off the trachea, that then, by the influence of the autonomic nervous system, the body shows manifold irritation-situations: through tension of the arrectores pilorum the hairs stand erect in the dorsal skin-regions of the trunk and in the tail; the bladder empties itself and also the rectum. In an entirely analogous way the sending of more powerful stimulants of the tonus to the skeleton-muscles takes place. The stimulants running centrifugally, which during life-time entertain the muscle-tonus by means of the thoracal autonomic nervous system, will now, at this increased irritability, after death cause a last powerful tonical shortening of the muscles.

When I had established in this way, that the occurrence of rigor mortis stands under the influence of the thoracal autonomic nervous system the question rose, if, at least in frogs, this influence, just like the tonus, as P. Q. BRONDGEEST [2]) has proved, is entertained by stimulants produced along the posterior roots of the spinal cord.

In this direction I made already 10 experiments. I cut the posterior-roots 8, 9, and 10 of a frog at one side. From the doctrine of segmental anatomy we know, that these posterior roots contain the sensitive nerve-tracts of the hind-leg.

[1]) Onderzoekingen van het Physiologisch Laboratorium te Utrecht 5de R. XI pag. 1. 1910.

[2]) P. Q. BRONDGEEST, Over den tonus der willekeurige spieren. Diss. Utrecht 1860.

Only such frogs as could still leap well after the operation, and in which from the leg at the operated side no reflexes could be excited, whilst it could be done at the other side, and that showed the so-called "Hebephaenomenon" of HERING were used for my experiments. I add here a few. protocols:

Ia. 6 *February*. Rana esculenta, of which posterior root 8, 9, and 10 of the left side are cut. The frog continues leaping after the operation and makes good use of the two hind-legs. The left hind-leg shows after the leap a new elevation of the foot as HERING has observed. Reflexes at the left hind-leg have ceased, a crossed reflex-movement through strong irritation of the right hind-foot is observed. The reflexes at the right side are lively.

7 *February* 9.30. The frog which is in a very good condition is hung at 30° Cels. in the damp case after the heart has been bound up.

12.30. The right hind-leg shows increased dorsal flexion in the foot-joint.

1.30. The dorsal flexion of the right leg has increased; when lifting the hind-legs a stronger resistance on the right side than on the left one, likewise in the knee and the hip. Left hind-leg still supple. Both fore-legs are likewise still supple.

2.30. Still the same situation as 1.30.

3.30. In right hind-leg still more resistance, left hind-leg still quite supple.

4 p.m. Right hind-leg is in stiffened tense and abduction position with expanded webs, foot-joint still supple.

5.30. The right hind-leg is quite stiffened in knee and hip, in the foot-joint partial rigor mortis. The left hind-leg is supple in all joints. On both sides there is rigor mortis in shoulder and elbow.

8 *February*. 10 a.m. The frog has been hanging from 5.30 last night in the damp case at 15° Cels.

The right foot is now likewise stiffened, so that the right hind-leg stands in entire tense and abduction position with expanded webs. The left hip is entirely stiffened, left knee and foot-joint are still movable.

9 *February* 10 a.m. The left leg is now also stiffened, only the knee is still somewhat, but very little, less stiff than the right one.

IIa. 10 *February*. Little Rana esculenta, of which on the 9th of Febr. posterior roots 8, 9, and 10 have been cut, on the leftside. Mobility and reflexes as with the former frog.

10 a.m. The heart is bound up. The animal is placed in the damp case at 30° Cels. for the experiment.

1.30 p.m. The dorsal flexion of the right foot has increased, likewise the hip flexion on the right side. Right hip begins to be stiffened, left hind-leg is still quite supple.

2 p.m. On the right side increase of the phenomena, on the left side still supple.

2.30. Right hind-leg almost quite stiff in still slightly flexed position, left hind-leg still supple.

3.30. Right hind-leg in stiffened tense and abduction position, the left one is stiff in the hip; knee- and foot-joint of the left leg still supple.

4.30. Both hind-legs are hanging in stiffened tense- and abductionposition with expanded webs.

IIIa Very large Esculent.

10 Febr. 10.45. The right posterior roots 8, 9, and 10 are cut.

11 p.m. After the heart has been bound up, the frog is placed in the damp case at 30° Cels.

3.30 p.m. Rigor mortis in the left hip.

4 30. Left hind-foot is entirely stiffened, only the foot is still a little movable. The right hind-leg is still quite supple. Both fore-legs are stiff. Now I remove the case with the frog to a surrounding of 17.5° Cels.

11 Febr. 10 a m. Right hind leg is now likewise entirely stiffened, only the foot is still partly supple.

11 Febr. 5 p.m. The right hind-leg is still somewhat supple in the foot-joint.

12 Febr. Both hind-legs stiffened in all joints.

IVa. *10 Febr.* The left dorsal roots 8, 9 and 10 of large Esculent are cut.

11 Febr. 9.30. Hung in damp case at 30° Cels

11.30. Right hind-leg with expanded webs, when lifting it the right leg shows increased resistance. Left hind-leg still quite supple.

1 p.m. Right hip rather stiff, left one still quite supple

3 p.m. Right hip rather stiff, right knee drawn up. Left hind-leg still quite supple.

5 p m. Right hip entirely, knee- and foot-joint partly still, much increased flexion position to the right. Left hind-leg still quite supple, the webs are here expanded.

5.30. Right hind-leg still in flexion-position, only the foot-joint is partly stiff; left hind-leg is still supple in all joints. Both fore-legs stiffened. Frog is now placed in a surrounding of 15° Cels.

12 Febr. 9 a.m. Situation still exactly the same as last night at 5.30. From this moment temperature at 30° Cels.

12 at noon. Left hind-leg begins to become still in knee and hip; right foot-joint still partly stiff.

1.30 p.m. Right hind-leg also stiffened in the foot-joint, entire tense-position; left hind-leg in tense position still in knee and hip, left foot is still partly supple.

Va. *12 Febr.* 9.45 a.m. Right dorsal root 8, 9, and 10 cut through.

10 p.m. The frog is hung in the damp case at 30° Cels.

1 p m. The left leg begins to draw up, the flexion in the hip and the dorsal flexion of the foot increase.

2 p.m. Left hip strongly flexed; left foot strongly dorsally flexed, on the left side increased resistance when lifting. Right leg still supple.

4 p.m. Left hip entirely stiff, knee and foot begin to be stiffened. Right hind-leg begins to draw up.

6 p.m Right hip and knee now likewise partly still, foot is still supple. Left hind-leg in tense position with still partly supple foot, right hind-leg in flexion-position.

13 Febr. 10 a.m. Both legs are hanging in stiffened tense- and abduction-position with expanded webs.

From these experiments, which I intend to continue it appears clearly, that the cutting of the appurtenant dorsal roots causes retardation of the rigor mortis of the muscles.

In this way we have proved that the view of HERMANN is incorrect, according to which the influence of the central nervous system on the occurrence of rigor mortis should be caused by the mortification of the higher centra by which impulses should be driven towards the muscles. For in my experiments in which I cut on one side the posterior roots, the way from the central nervous system to the muscle is nowhere interrupted; only the supply of reflexstimulants (from the proprioceptores) is prevented. Rigor mortis is consequently also caused by a reflectoric process.

If we ask now how we are to understand the tonical innervation for accelerating rigor mortis, the answer must run, in my opinion, pretty well as follows.

We know from FLETCHER and WINTERSTEIN that the indispensable cause of rigor mortis is to be found in a chemical state of the muscles, which is caused by want of oxygen.

This "chemical state" will certainly depend on the existence of products of metabolism. It is for the present unknown which are these products. There are however, I surmise, sufficient reasons to admit that they are products of partial transmutation, for supply of oxygen, which certainly encourages transmutation, prevents rigor mortis, and increase of temperature which also promotes transmutation, accelerates rigor mortis.

We can reconcile these two facts in no other way than by admitting that in the first case the ample supply of oxygen causes the processes of metabolism to take their normal courses to the end, consequently to complete oxydations, during which then the obnoxious intermediate products do not come into existence, or do not continue to exist. In this way it is also comprehensible that increase of temperature promotes rigor mortis so much,because with the metabolism, taking place then with still greater rapidity and intensity, the want of oxygen, resp. the deficit of oxygen, is felt so much the stronger.

If now in this respect we compare the two hindlegs of a frog of which on one side the reflex-stimulants for the tonus have no longer access, then the leg with intact reflex-track has muscles that are in a state of tonus, whilst the tonus in the other side has disappeared. The leg with muscles in tonus, requiring for the entertainment of this situation more metabolism will consequently show a more rapid and intensive accumulation of intermediate products of metabolism than the atonic leg, which does notrequire so much oxygen on account of less intensive metabolism.

Consequently the muscles that are in a state of tonus satisfy better the indispensable condition of rigor mortis, namely suffocation, than the atonic ones. The leg with tonus muscles also satisfies better the 2nd condition namely the condition of being influenced by the nerves.

For these muscles constantly receive indeed stimulants by way of reflection, whereas the other atonic leg remains without these stimulants. The consequence of both the more intense alteration of the chemical state and the influence of the reflection is that the leg of which the tonus-reflection track remains uninjured, stiffens sooner than the leg of which this reflection-track is interrupted at the posterior roots or near the Rami communicantes. We must thus consider the rigor mortis of the skeleton muscles as a last vital demonstration of the muscles under the influence of suffocation, whilst stimulants running along the tonus-reflection-track accelerate this process. That rigor mortis is a last (tonical) contraction of the muscles is apparent from the fact that the muscles that have lost their irritability in an atmosphere of oxygen, can no more stiffen or shorten under circumstances of suffocation.

Chemistry. — *"On the reduction of aromatic ketones"*. II. By Prof. J. BÖESEKEN and W. D. COHEN. (Communicated by Prof. A. F. HOLLEMAN).

(Communicated in the Meeting of February 28, 1914).

In our previous communication on this subject [1]) we have assumed that by reduction of the ketones the half pinacone molecule is in all cases the sole direct reduction product.

If, in the position where that partial molecule is formed, there are practically no OH-ions it polymerises immediately to pinacone.

In the presence of OH′, however, there was always found benzhydrole and the question arose whether this was caused by direct reduction or by the transformation of the previously formed pinacone into benzophenone and benzhydrole by the OH-ions.

These alternatives may be represented by the schemes

$$(C_6H_5)_2CO \rightarrow (C_6H_5)_2COH \rightarrow (C_6H_5)_2CHOH \quad . \; . \; . \quad (I)$$

$$(C_6H_5)_2CO \rightarrow (C_6H_5)_2COH \rightarrow [(C_6H_5)_2COH]_2 \rightarrow (C_6H_5)_2CHOH + \\ + (C_6H_5)_2CO \quad . \; . \; . \; . \; . \; . \; . \; . \quad (II)$$

1) Proc. XVI, 91 (1913).