THE PHYSIOLOGICAL PROPERTIES OF 'WEST AFRICAN BOXWOOD.'

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In the summer of the present year I was asked by the Amalgamated Society of Shuttlemakers to give an opinion on the nature and properties of a timber used in the manufacture of shuttles in Lancashire and Yorkshire, and believed by the workmen to have an injurious effect on the health of those employed in the trade.

On enquiry I found that the wood was known under the name of 'West African Boxwood,' and that it had been in use during the past few years for shuttle manufacture, though, at first, only sparingly and intermittently. The recent increase in its use was due to its cheapness as compared with Persian Boxwood and to its freedom from knots, permitting thereby a larger number of blocks being obtained from the log.

I was also informed that during the past two or three years there had been many cases of illness amongst the workmen handling the wood in the factories, and that an impression had got abroad that the sickness was due to some poison given off by the wood during the process of manufacture of the shuttles. The symptoms complained of were headache, sleepiness, running at the nose and eyes, chronic sneezing, giddiness, faintness and weakness, loss of appetite, shortness of breath, nausea, etc. The patients exhibited as well a pale yellowish or greenish colour on the face and body, accompanied by a peculiar 'camphor' or 'Turkey rhubarb' odour from the breath and skin. After weeks of intermittent illness these symptoms had, in two or three cases, culminated in pathological conditions which had resulted in death, the death certificates registering 'cardiac asthma,' or 'cardiac incompetence.' I was also informed that the men who were affected had, in the course of their work, to stop, hold on to some support and gasp for breath. Samples of the wood, together with a quantity of the

sawdust and shavings, were sent me for investigation by Mr. Isherwood, Secretary of the Shuttlemakers' Society. The enquiry, obviously, resolved itself into (a) the discovery of the botanical name of the wood and its economic history ; (b) its chemical characters ; (c) the physiological properties of any extract which might be obtained from it. I should like at once to acknowledge the very great assistance I have received from my colleague, Dr. A. W. Titherley, Lecturer on Organic Chemistry, and from Miss Sowton and Professor Sherrington, F.R.S., in the purely chemical and physiological aspects of the investigation respectively. Without their aid the work could not have been accomplished. I am also indebted for information on several points to Messrs. Joseph Gardner and Sons, of Bootle ; to Dr. Legge, Chief Medical Inspector to the Factory Department of the Home Office ; to Lord Mountmorres, Director of the Liverpool School of Commercial Research in the Tropics ; and to B. Daydon Jackson, Sec. L. Soc.

It was obviously of primary importance to determine what was the botanical source of the wood. As all who deal in timbers are aware, it is often extremely difficult to collate a popular name with a botanical source, and the present instance proved to be no exception to the rule. A glance at the microscopic characters of the wood at once revealed the fact that, though called 'boxwood,' it was not a species of *Buxus* at all events. The wood has been apparently confounded with West Indian Boxwood ; but that wood is, according to Stone (*Timbers of Commerce*, p. 169) a member of the Bignoniaceae, 'reputed to be *Tabebuia pentaphylla*, Hemsl,' having histological characters resembling those of *Buxus*. The wood supplied to me was certainly not 'West Indian Box,' and from its port of shipment, one was led to look for another botanical origin. I was finally led to believe it to be *Sarcocephalus Diderrichii*, De Wild. and Dur. (in De Wildeman, *Notices sur les plantes utiles ou interessantes de la flore du Congo*, Brussels, 1903), a member of the order Rubiaceae. According to the 'Guide de la Section de l'État Indépendant du Congo a l'Exposition de Bruxelles-Tervueren', 1897, the wood was known also as 'yellow grey box' (Bois-gris-jaunâtre), and said to be shipped from Mayumbe, W. Africa. I found that it

was also known as 'Yellow Congo Mahogany' (acajou jaune du Congo). It was said to be characterised by the presence in it of small pockets containing a solid matter of yellow ochre colour and small, quite translucent, prismatic crystals. It was called by the natives 'N'gulu Maza' or 'N'gulu na mai' ('river' or 'water hog'), from the supposed resemblance of its rough grained bark to the skin of the wild boar or hog. The wood is of a pale golden colour when freshly cut, but rapidly fades to a yellowish-white, with brightly-coloured patches. It forms a capital cabinet wood, difficult to work on account of its cross grain, but still capable of delicate manipulation owing to its hardness, and taking on a high polish. The specimens which were supplied to me agree in all respects with this diagnosis.

The wood has also been confounded with 'East London Boxwood' (*Gonioma Kamassi*, E. Mey.), a member of the Apocynaceae, also a poisonous order, although I have not tested that wood chemically or physiologically. In general appearance the wood of this species closely resembles that of *Sarcocephalus*, but the tapering medullary rays of the former would seem to distinguish it under the microscope from West African Boxwood. Personally, I do not think very great stress can be laid on minute histological characters, for the size of the vessels, thickness of the medullary rays, and other characteristics must vary greatly according to the climatic conditions under which the tree has grown. Undoubtedly such histological characters are not to be neglected, for it is well known that the woods of different species from the same order show family resemblances; but I do not believe that it is possible with absolute certainty to refer a timber to its species from histological features only. *So far at least as I can judge*, the timber known as 'West African Boxwood' is not identical either with 'South African Boxwood' or with 'West Indian Boxwood.' South African boxwood is shipped from Mossel Bay and Knysna, and is an inhabitant of South Africa, while the subject of the present investigation is a native of the Congo basin and the Cameroons; in any case, the wood, whatever be its source, possesses the chemical and physiological characters described below—the point of importance at present.

After a consideration of the circumstances governing the mode of manufacture of the shuttles it seemed to me that the injurious symptoms might be accounted for by the absorption of some poisonous alkaloid present in the fine dust produced during the manufacture of the shuttles, and this idea was strengthened by the fact that the plant appeared to belong to an order well known to possess alkaloids, viz., the Rubiaceae. On enquiry I found that the logs were first of all sawn into lengths from which blocks of the proper size (12 in. $\times$ 1½ in. $\times$ 1½ in.) were cut. The edges of the block were then 'dressed,' and the block 'bored' and 'tipped.' The interior was afterwards cut out and the ends turned in a lathe, the shuttle being finally 'finished,' so far as the wood was concerned, by being polished with sand paper. The whole series of processes, save the 'finishing,' is carried out by machinery. Finishing is, however, done by hand, and each finisher works, I was told, for about one hour per diem at this phase of the manufacture. Naturally much dust is created, more especially in the final sand-papering stage, when the workmen are extremely lightly clad, being often naked from the waist upwards. I was told that the sickness was most prevalent among the workmen whose duty it was to saw the logs into 'blocks,' and among those who polished the chiselled shuttle with sand paper into the final finished product. Such men were constantly enveloped in a cloud of fine dust, 'like smoke,' given off by the saws or lathes, and were under circumstances such that the inhalation of the dust or absorption of it by the skin was unavoidable.

The first thing to be done was, obviously, to extract the alkaloid from the dust—assuming that an alkaloid was present. This was accomplished in the following manner:—A kilogram of the dust was extracted with four litres of water, at a temperature of 70-80° C. To this was added 100 c.c. of concentrated hydrochloric acid, the whole being agitated and digested for four hours. The liquor was then filtered, and the ligneous material well washed. The combined filtrate and washings were concentrated down to two litres, such resinous matter as was present, and which had separated out was filtered off and the clear brown solution, was precipitated by an excess

or potassium-bismuth iodide. A voluminous, orange-brown precipitate was obtained (a double compound, alkaloid-bismuth-iodide) which was collected and well washed with water. The precipitate was then decomposed by an excess of a 10 per cent. solution of caustic soda, in order to liberate the free alkaloid, and the mixture was extracted twice with about 100 c.c. of freshly-distilled chloroform. A certain amount of emulsification was unavoidable. After settling, the chloroform extract was washed with water and, finally, all traces of moisture were removed by filtration. The chloroform solution, which was deep brown in colour, was then distilled on a water bath to remove most of the chloroform, the last traces being removed by heating at 80-90° C. in an open glass dish. A thick, dark brown syrup remained over, consisting of the free alkaloid which, on cooling, solidified into an amorphous, brittle, glassy solid. It weighed 0.7 gr., representing 0.07 per cent. of alkaloid in the wood. Assuming that it had been possible to extract all the alkaloid, the wood may be taken as containing 0.1 per cent. of the alkaloid.

The alkaloid was then converted into the hydrochloride by digestion with dilute hydrochloric acid (5 per cent.) the whole being evaporated to dryness on the water bath. The residue after evaporation was then dissolved in water and filtered from about 0.2 gr. of resinous insoluble impurity, and the filtrate was diluted so as to contain 0.7 per cent. alkaloid hydrochloride. The alkaloid when examined in detail was found to be very soluble in chloroform and in alcohol (though less so), sparingly soluble in water, but the hydrochloride was readily soluble in water and salt solution. On heating, it decomposes, chars and gives off a vapour with a peculiar and penetrating odour. On adding caustic soda or Na_2CO_3 to a solution of the hydrochloride the free alkaloid is thrown down as a yellowish, amorphous, curdy precipitate. It was found to be impossible to obtain it in the crystalline form by dissolving it in hot water and cooling. The alkaloid gave the following reactions :—

- (a) Bismuth iodide in potassium iodide gave a bright orange precipitate even in very dilute solutions.
- (b) Iodine in potassium iodide gave a dirty brown precipitate coagulating in dark brown masses.

(c) Nessler's solution gave a whitish-yellow precipitate.

(d) Tannic acid gave a gelatinous white precipitate.

(e) Picric acid gave a yellowish precipitate.

(f) Platinic chloride gave a yellow precipitate in strong solutions.

(g) Phosphomolybdic acid gave a thick pale yellow precipitate.

The solutions used for experimental purposes were (a) a solution of the alkaloid in alcohol, and (b) a solution of the hydrochloride in water.

The fluid (a) actually used was a 1 per cent. solution of the alkaloid in absolute alcohol, diluted to ten times its volume with Ringer's solution. This will be referred to in the experiments to be described, as 'A' solution; the other (b) was a 0.7 per cent. solution of the hydrochloride in water and will be styled 'B' solution.

Before describing the experiments themselves it may be advisable, perhaps, to summarise briefly some of the data furnished me by the Secretary of the Shuttlemakers' Society, amplified by notes kindly put at my disposal by Dr. Legge, H.M. Chief Medical Inspector of Factories, whose attention was called to the matter in consequence of my report on the wood to the Shuttlemakers' Society.

Dr. Legge* informs me that he examined about 65 per cent of the men engaged in working the wood in a number of factories visited and found that about 32 per cent. complained of headache lasting for from two to four hours after beginning to work the wood, and continuing for from two to three days after discontinuance. The headaches were described as 'over the eyes or at the temples.' Eleven per cent. complained of sleepiness, the feeling being described by the men as 'mazineess' or 'dosiness,' and in some cases being so pronounced as to necessitate a strong effort of will to avoid falling off the bench. Fourteen per cent. complained of running at the eyes, and about 29 per cent. of running at the nose. These symptoms appeared only when African Box was used. (I may add here that other woods are employed for the manufacture of shuttles, e.g., Persian Box, Persimmon, Cornel, etc., as well

* Since this paper was written Dr. Legge has examined several other factories, and he informs me that the cases he enquired into quite bear out his former investigations.

as W. Indian and S. African Box, above referred to.) The 'running' was not accompanied by any ulceration but local inflammation of the mucous membrane was observable. Breathing was affected in 35 per cent. of the cases noted. The condition was such as to compel several men to give up work on the wood and the poison seemed to affect expiration rather than inspiration, hence leading to the accumulation of mucus in the trachea. About 10 per cent. complained of nausea and faintness. In most cases, two or more symptoms were complained of by the same individual. Thus one man stated that he had suffered from frontal headache, running at the nose, pains in the limbs and shortness of breath. These symptoms disappeared when he changed from the wood to the metal department. Another, a sawyer, complained of frontal headache, dizziness, nausea and difficulty in breathing. This workman left off work for six weeks and recovered, but had a renewal of the attacks a few days after starting work once more. Another 'finisher' suffered from asthmatic symptoms which were, according to his medical adviser, affecting the heart to such a degree that he was recommended three months' rest. After an interval of one month, the workman in question returned to work, but in a few days the same symptoms reappeared. After an interval of two months he once more returned to work and soon began to suffer from dyspnoea, palpitation, and a sensation of suffocation. He has done no work during the last few months and has had no recurrence of the attacks. On the other hand, Dr. Legge informs me that one man who had sawn over one hundred tons of West African Boxwood had suffered no inconvenience at all, and suggests that individual idiosyncrasy may play some part in determining the occurrence or the severity of the symptoms. This, so far as I am aware, agrees entirely with the effect of the poisons occurring in such plants as *Rhus Toxicodendron*, *Primula obconica*, *Asparagus officinalis*, etc. In some cases these plants produce severe eruptions on the face and hands of those touching them, whilst in other cases the poison produces no effect whatsoever. It is possible, however, that the workman referred to may have mistaken the wood on which he was employed for West African Box.

I append here a detailed report on a 'case' kindly put at my disposal by Dr. Hamilton Stewart, of Bradford, as an instance of the specific effect of the dust of West African Box.

Case. Aged 38. Employed for between twenty-four and twenty-five years as a 'finisher off' at the shuttle shop in Thornton.

Previous history and health :—

- (1) He is a married man with a family of six—all healthy.
- (2) His previous health was good until seven or eight years ago, when the present symptoms began.
- (3) His family history is good. Both his mother and father are alive—the latter has occasional epileptic attacks.

(4) *Present illness :—*He dates the beginning of the present illness from seven years back. West African Boxwood has only been worked, so far as he remembers, in this shuttle shop for the last ten years, and that only occasionally. It has never, since they began using it, been worked continuously, but only occasionally for varying periods of time. At first he worked the wood a good deal—'dressing up,' and he did not experience any evil effects for about three years. Then the symptoms from which he now suffers, when working with that particular wood, began.

History of the attack :—

The attack began with running of the eyes and nose, and a feeling of suffocation. He had a feeling of nausea and sickness, with violent retching. He felt *faint* and *done*, so much so that he felt a desire to lie down—a desire he could not gratify owing to the difficulty he had in breathing. He complained of a slight pain and uneasiness over the cardiac region, and broke into a cold, clammy sweat. His breathing gradually became worse, more rapid and difficult, so that he could neither speak nor swallow. When in the fresh air his symptoms seemed to him to be at first aggravated, and then gradually to pass off.

The duration of the attack depended on the length of time he had stayed at work. If he stayed at work now for, say, ten minutes when this wood was being used, he took two or three hours to recover, but if he remained at work one or two hours, two or three days passed before recovery was complete. Lately it has begun to affect him more quickly than it used to do. If the wood were being used now and he went to work on it, he would be retching violently in about ten minutes. At times he has been working in one of the upper rooms of the workshop, where he could not see and did not know what wood was being sawn up. So soon as the dust began to work its way up, his symptoms began. After one very severe attack he was three weeks at home, and three weeks at Ilkley Convalescent Home to recruit, and finally felt quite well. He returned to his work but, unfortunately, they were using this wood, and that same day he was as bad as ever.

Now that this wood has not been in use at this workshop for a long time, he is quite healthy, strong and active, and has not lost any time.

Physical Condition during the Attack :—

He was seated upright on a chair, gasping for breath, with the door of his house wide open. He had a somewhat livid appearance, and the skin was cold to the touch, and covered with a cold, clammy perspiration. His temperature was normal. He could not lie down, and the difficulty of breathing was such that he could just jerk out a word or two in answer to questions. His eyes were red and somewhat swollen, and both eyes and nose were running. There was no ulcerative condition of the inside of his nose, but the mucous membrane was swollen, and he complained of his nose feeling twice the size it ought to do. He complained of no headache or feeling of sleepiness. He kept constantly retching and trying to vomit.

Circulatory System :—

He complained of slight cardiac pain and uneasiness, and dyspnoea was marked. The pulse was frequent and about 100 per minute. It was regular but soft, small and easily compressed. The apex of the heart was in its normal position, and the palpation could scarcely be felt.

On auscultation the valve sounds were normal in character, but weak and muffled, and, altogether, gave one the impression that the heart was rapidly failing.

Respiratory System :—

Respiration was quick and laboured. The dyspnoea was marked and was of the expiratory kind. He had a great deal of difficulty, evidently, in emptying his chest, and had to sit up straight in his chair and use his forced muscles of respiration.

There was no dulness on percussion or increased resonance.

On auscultation the inspiratory sounds were fairly normal, but expiration was prolonged and piping. Beyond the piping expiratory sounds there were no rhonchi to be heard.

Digestive System :—

This seemed normal, with the exception that he complained of a bitter taste in his mouth, and of the violent retching. All the other organs were normal and there was no albumen in the urine.

Diagnosis :—

When I first saw him during a severe attack, I was quite at a loss to account for his symptoms. The attack looked somewhat like an ordinary attack of spasmodic asthma caused probably by the inhalation of dust, yet I had never before seen an attack of asthma cause so much cardiac depression in such a short time. On the other hand, it did not quite conform to the ordinary type of cardiac dyspnoea—there was more difficulty with the expiration than is usual with such attacks, and there was no evident cardiac valvular lesion. The attack seemed to come between an ordinary attack of asthma and one of cardiac asthma.

I saw him in several other attacks, and in talking the matter over with him he told me that he had noticed that he always had an attack when they were working this wood. I came, therefore, to the conclusion that it was the dust of this special

wood that was so deleterious to him, and I accordingly advised him to leave his work when they began working West African Boxwood. He tried a respirator with cotton wool in it for a time but he felt suffocated in it and had to discard it.

We may now turn to the discussion of the physiological effect of the alkaloid on the mammalian heart as evidenced by the sphygmographic records kindly prepared for me by Miss Sowton in the Thompson Yates Physiological Laboratories of the University.

The heart used was that of the cat, removed from a recently killed animal, and perfused with a salt solution prepared according to Ringer's formula at body temperature. The flow through the heart was maintained by means of oxygen pressure.

EXPERIMENT I (with solution 'A')

(a) *Control Experiments*.—In using solution 'A' it was manifestly necessary to know what share in the results obtained was due to the presence of the alcohol in which the alkaloid was dissolved, so that control experiments were first of all carried out before any of the alkaloid was injected. Three such controls were recorded, and it was found that (using 7 c.c. of alcohol) at the first and second injections the heart beat was almost instantly stopped but for a short time only; at the third injection the heart had become accustomed to the dose, and the effect was masked.

(b) *Observation 1* (Fig. 1).—2 c.c. of solution 'A' was next injected by means of a hypodermic syringe into the perfusion tube, about three feet away from the heart, after it had regained its normal beat. The solution 'A' was thus well mixed with the perfusion fluid. The immediate effect was a slowing of the heart and a rapid reduction to zero. The time of injection lasted fifty-five seconds. Ten seconds after the injection was begun the slowing of the heart-beat followed, and twenty seconds later had entirely ceased. The heart remained quiescent for about 180 seconds, or about $2\frac{1}{2}$ minutes after the injection had ceased. The heart then commenced beating very feebly, and with a much slower rhythm, gradually increasing in vigour and still more gradually in speed.

Observation 2.—When the heart had again regained a normal but slower beat, 5 c.c. of solution 'A' were injected in the same way as before, the time of injection lasting rather over one minute (70 seconds). Within half a minute of the first injection the heart began to slow and decrease in vigour, and finally at the end of the injection period came to a standstill. The cessation was permanent for about seven minutes, when the heart began to show feeble attempts at contraction, and a minute later more or less regular but very slow beats (about one beat every five seconds). The heart showed no signs of permanent recovery.

EXPERIMENT II (with solution 'B')

Observation 1.—Solution 'B' was diluted to one in ten with Ringer's saline and 8 c.c. of the mixture was slowly injected (the period of injection lasting 2 minutes, 45 seconds). A few seconds after injection commenced the vigour of the beat rapidly fell to one-sixth of the normal, and in about half a minute fell to nil, the heart remaining quiescent for half a minute after the injection had ceased. It then began slowly to recover, the beats being at first very feeble and slow, but increasing both in strength and in rhythm, until, about three minutes after, the beat was again fairly normal though not quite so rapid as at first.

Observations 2 and 3.—Short injections of 10 c.c. of the fluid escaping from the heart produced only a slight effect.

(b) *Control experiment 4.*—At this stage 10 c.c. of Ringer's Saline without alkaloid were injected but no effect was produced.

(c) *Observation 5* (Fig. 2).—The solution 'B' was again used but this time diluted with Ringer's saline to one part in five of the saline. Of this fluid 5 c.c. were injected. The beat rapidly slowed down and ceased twenty-five seconds after the injection had been begun. The injection lasted two minutes, during which time and for sixty seconds longer the heart was entirely quiescent. Then followed a slow and gradual recovery, the rhythm, however, never reaching the speed of the original heart beat. (It is of interest to note in this relation that several of the workmen suffering from the action of the wood-dust

also shewed a very slow pulse, one case, as Dr. Legge informs me, being as low as fifty).

Observation 6 (Fig. 3).—In this experiment 2 c.c. only were injected but the delivery was very rapid, viz., under ten seconds. The effect was almost instantaneous, the heart ceasing to beat within about five seconds, and remaining practically quiescent for $1\frac{1}{2}$ minutes, when very slow and feeble pulsations recommenced, gradually, but very gradually, increasing in vigour and rapidity to the normal once more.

All the observations hitherto recorded were carried out by the syringe method of delivery in order to economise the material, which, as will have been seen from the description of the method of preparation, was obtained only by a long and laborious process. The syringe method permits of only approximate estimation of dosage and hence, in the experiments yet to be described, the more exact method of administering the dose in full stream from a flask, containing a mixture of solution 'B' and Ringer's saline made up before-hand to the required strength, was adopted. The flask used was similar to that containing the normal Ringer's saline and was under the same oxygen pressure, and the change from normal saline to drugged saline and back again was effected by means of a system of three-way taps, connecting either flask with the delivery tube immediately before the delivery tube enters the heart.

EXPERIMENT III (with solution 'B')

Observation 1 (Fig. 4).—In this experiment carried out as above described, solution 'B' was diluted to 0.023 per cent., and administered for fifty seconds. In all, 33 c.c. of the fluid passed through the heart. The effect was a rapid slowing and final stoppage within thirty seconds of the beginning of the injection; quiescence continued for about a minute after injection had ceased, when the heart began to slowly recover both in vigour and in rhythm.

Observation 2.—The same degree of dilution of solution 'B' was employed, but the fluid was administered for six minutes, five seconds, 142 c.c., in all passing through the heart. In this case within half-a-minute the heart had ceased to beat, continued quiescent during

the entire period of injection, and for several minutes afterwards, and, though recovering very feebly and slowly, it appeared to be permanently injured.

EXPERIMENT IV (with solution 'B')

Solution 'B' was diluted to 0.0077 per cent. and administered for 1 min. 45 sec. The beat rapidly slowed and decreased in vigour, reaching a standstill, with occasional spasmodic flickers, before the end of the injection. The tracing showed that the heart never recovered, and only evinced occasional spasmodic contractions of feeble power and most irregular rhythm. The heart was undoubtedly permanently injured.

EXPERIMENT V

Solution 'B' was diluted to 0.0026 per cent., and administered for four minutes, thirty seconds, 48 c.c. of the fluid in all passing through the heart. The beat declined very gradually, disappearing by the end of three minutes. Recovery was very imperfect, and even when they recommenced, the beats were very much slower and most irregular.

EXPERIMENT VI

The solution 'B' was still further diluted, viz., to 0.0013 per cent., and administered for about eight minutes, when the solution began to give out. The beat was very slowly retarded, and became gradually feebler; recovery was fair, but never became complete.

CONCLUSIONS

The net result of all these experiments is to show that the alkaloid present in 'West African Boxwood' is a cardiac poison, inducing a gradual slowing of the heart-beat and diminution of vigour in the contractile tissue of the heart; that its effect is cumulative, finally producing a cessation of the beat under long exposure to its influence. The fact that the alkaloid is very soluble in saline solution should, it appears to me, be noted along with the fact that the perspiration contains a considerable percentage of salt, and that,

according to Waller (*Human Physiology*, 1896) the palm of the hand (the part of the body most exposed to the action of the dust in the case of the workmen concerned) gives off more moisture, area for area, than any other part of the body surface. I have no doubt in my own mind that the fine particles of ligneous matter of the wood in question falling on the perspiring skin—more especially of the hands—gave up in variable quantity the alkaloid extracted which became absorbed into the circulation, and ultimately affected the heart of the worker and induced indirectly the various symptoms described in the preceding pages.

FIG. 3

Tracing from cat's heart after injection of 2 c.c. of solution B lasting 10 secs. See text, Experiment II, Observation 6. Tracing to be read from right to left. Time interval, 5 secs.

FIG. 4

Tracing from cat's heart after injection of 33 c.c. of solution B. See text, Experiment III, Observation 1. Tracing to be read from right to left. Time intervals, 5 secs.

FIG. 1

Tracing from cat's heart after injection of 2 c.c. of solution A. See text, Experiment I, Observation 1.
The tracing is to be read from right to left. Time record in 5 sec. intervals.

FIG. 2

Tracing from cat's heart after injection of 5 c.c. of solution B. See text, Experiment II, Observation 5.
Tracing to be read from right to left. Time intervals, 5 secs.