# An Improved Technique for the Electrocardiographic Recording of Fish

by

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## Abstract

Fifty fish, *Cyprinus carpio*, living free in water of aquarium were used for the experiment of a technical improvement of recording electrogram of heart. A typical pattern of electrogram which is similar to that of Lead II of human ECG was taken when the indifferential electrode was inserted vertically into the left side of belly above anterior portion of pectorial fin and the other exploring electrode was inserted into the dorsal margin of the left gill slit. It was shown from this report that the duration of QRS complex in fish electrogram is not longer than 0.06 seconds and heart rate is 36.5 beats per minute in average. The heart rhythm increase sharply even to two times more than that of original after stimulation with needle. A concentration of adrenalin in 0.048 mg per kilogram of body weight will induce sinus arrhythmias. Hypoxia have an effect to slow down heart beating.

## Introduction

Though the ECG of fish had been recorded from a number of fish by some investigators ( 9 , 11 , 17 , 19 ), there was still few ECG tracing from the *Cyprinus carpio*. Furthermore, the method of so-called unipolar leads was not been used yet for a recording of ECG from a living and free fish ( 6 , 9 , 15 ). Generally speaking, the functional systemic heart of *Cyprinus carpio* consists of four parts ( chambers ) in series ( see Fig.1 ). Venous blood entering the sinus venus from the liver and ducts of cuvier is pumped first into the auricle, then into ventricle, and finally into the ventral aorta via a bulbus arteriosus. The present investigation was performed for :(a)

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an improvement on the laboratory approach and procedure for recording electrogram of fish heart. (b) the fundamental ECG pattern of the fish that are alive and free in water was to be registered by using the method of unipolar leads. (c) a preliminary work for advancing study of pharmacologic action in fish heart. (d) a comparison with that of human heart.

## Methods and Materials

Fifty fish of *Cyprinus carpio* , *L.* ( a native of Taiwan ) in various size from 600 gm to 1000 gm in weight and in both sexes of fish were used in this investigation. Let experimental fish free in the water of aquarium ( 100cm × 60 cm × 40 cm )which was filled with water to 80 per cent of the total volume of chamber and was kept in good working condition at 25°C water temperature by btbbling air or oxygen ( $O_2$ 95 % and $CO_2$ 5 % ) through a tube. A silver needle ( indifferential electrode ) insulated with polyethylene was inserted into the left side of belly above the pectoral fin and the other electrode ( exploring electrode ) was inserted into the mid-line or the left paramidline of the anterior portion of the abdomen ; another needle ( ground electrode ) was placed at any point of belly. Keep animal free in water connecting with recording needles and monitor untill fish become breathing regularly. It is necessary to avoid destroying scales and vessels during insertion of needles. Many investigators ( 7 , 9 , 10 , 11 , 17 , 19 ) stated that the fish injuried by this way soon show irregularities of heart beat or atrio-ventricular block.

The electrocardiogram was taken with a Fukuda Cardiette Apparatus- CARDIANT CENTURY FCC-1. The electrodes connected with leads of apparatus are as follows: the needle ( indifferential electrode )located in the left side of the body was connected with RA lead of the apparatus , whereas the exploring electrode , the needle located at the anterior portion of the abdomen , was connected with LF lead of the apparatus ; while the ground electrode was connected with LA lead of the apparatus or just put in water , and the selector switch was put on Lead II. The voltage standardization of the apparatus was turn to 10mm in each mV. and the legend of each figure announces the used standardization. The speed of recording trace was run at 2.5cm per second. In order to obtain a typical and an easy interpretation of the electrocardiogram of fish, we must make sure the location of the exploring electrode. To determine the location of the exploring electrode, we had done a pre-experiment in which the chest of fish was exposed by a incision. Then, placed the exploring electrode on surface or beneath of heart to find suitable points of which various electrogram patterns were recored and was drawn as Fig. 1. Care was taken to make fish in fresh condition and a normal heart rhythm for avoiding the abnormality of elevating ST segment or atrio-ventricular block which occurs when the experiment had been working for a long period ( see Fig. 3).

## Results

The electrogram of the fish heart recorded by this experiment is similar to that of other kinds of fish. Typically , P wave is followed by a QRS complex and a T wave. The activity of the auricle taken from the surface of the ventricle at the left side of belly shows a quick and a slow phase and can be registered as the P wave which is si-

milar to that of human electrocardiogram. The P wave is mainly downward if electrode was placed on the surface of sinus venus, and a biphasic wave results when electrode was inserted on the surface of auricle at the left side of belly (see Fig.2).

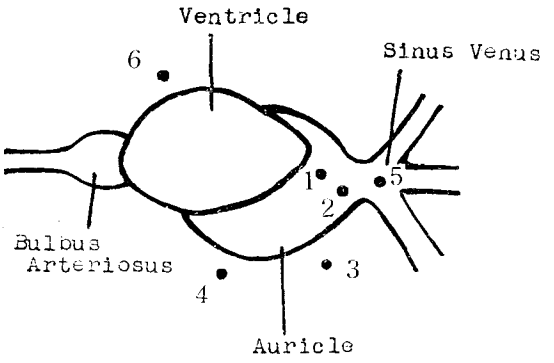


Fig.1. An outline of the heart of *Cyprinus carpio* in which various sites of inserting needles are shown.

The electrogram of ventricle of fish heart consists of QRS complex and T wave. We got such a perfect pattern as that recorded from a normal human by Lead II when needle was inserted at point 6 shown in Fig.1(see Fig.2).Two features are most conspicuous in the tracing , namely , the relative short duration of QRS complex which normally is not longer than 0.06 seconds , and the rather long duration of the QT interval(see Table 1).As a rule the QT interval is quite of long duration even for a fast heart rate.At the slow rate the PR interval and QT intervals may be longer,but the increasing ratio is not so evident as the ventricular activation time ( VAT: the duration of which an impulse to transverse from the endocardium to the epicardial surface ).

Table 2 gives the heart rate with the regular A-V sequence recording from normal fish free in water.The rate may increase to a maximum of 145 beats per minute if the ventricular surface of chest-opened fish was stimulated with a single shock no more than 3 voltages, while a single needle stimulation only can accelerate heart rate twice in average and show a significant difference ( Table 2 ).Atrio-ventricular block will be present on the tracing if a experimental fish was done more than 6 hours or without bubbling air or oxygen through water of aquarium( see Fig.3 ).The result is much similar to that of other investigators ( 8 , 13 , 14 , 16 ).An injection of 0.048 mg per kilogram body weight in 0.025 ml solution

Table1 The duration of the electrocardiogram of *Cyprinus carpio* living free in squarium at 25°C water temperature.

| | Heart rate (beats/min.) | P—Q (sec.) | QRS (sec.) | VAT (sec.) | Q—T (sec.) |
|---|---|---|---|---|---|
| | 36 | 0.112 | 0.032 | 0.020 | 0.352 |
| | 37 | 0.110 | 0.040 | 0.026 | 0.340 |
| | 39 | 0.108 | 0.044 | 0.036 | 0.384 |
| | 39 | 0.092 | 0.036 | 0.028 | 0.320 |
| | 35 | 0.182 | 0.060 | 0.036 | 0.520 |
| | 38 | 0.096 | 0.048 | 0.033 | 0.370 |
| | 33 | 0.168 | 0.056 | 0.028 | 0.481 |
| Average | 36.1 | 0.1207 | 0.0451 | 0.0294 | 0.3954 |

of adrenalin into hepatic vein during chestopened experiment produced the sinus arrhythmias without changing rate of ventricular contraction ( see Fig.3 ).

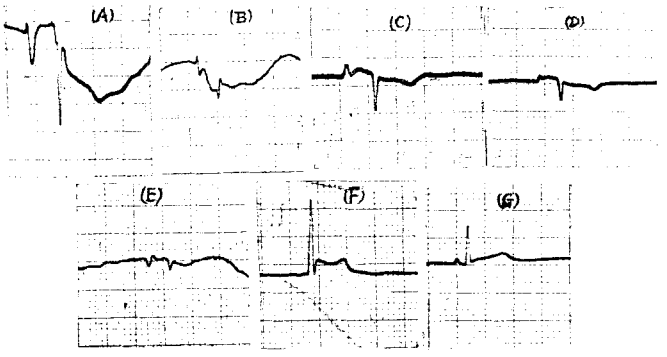


Fig.2. Electrocardiogram ( 1mv = 10mm) of *Cyprinus carpio* recored from an " open-chest " fish by placing exploring electrodes at the different points (shown in Fig.1 ) around the heart: (A) from point 1 , (B) from point 2, (C) and (D) from the lateral side of auricle ( point 3 ), (E) from sinus venous (point 5), (F) from the left lateral side of ventricle ( point 4 ), (G) from the outer surface of the abdomen near point 6.

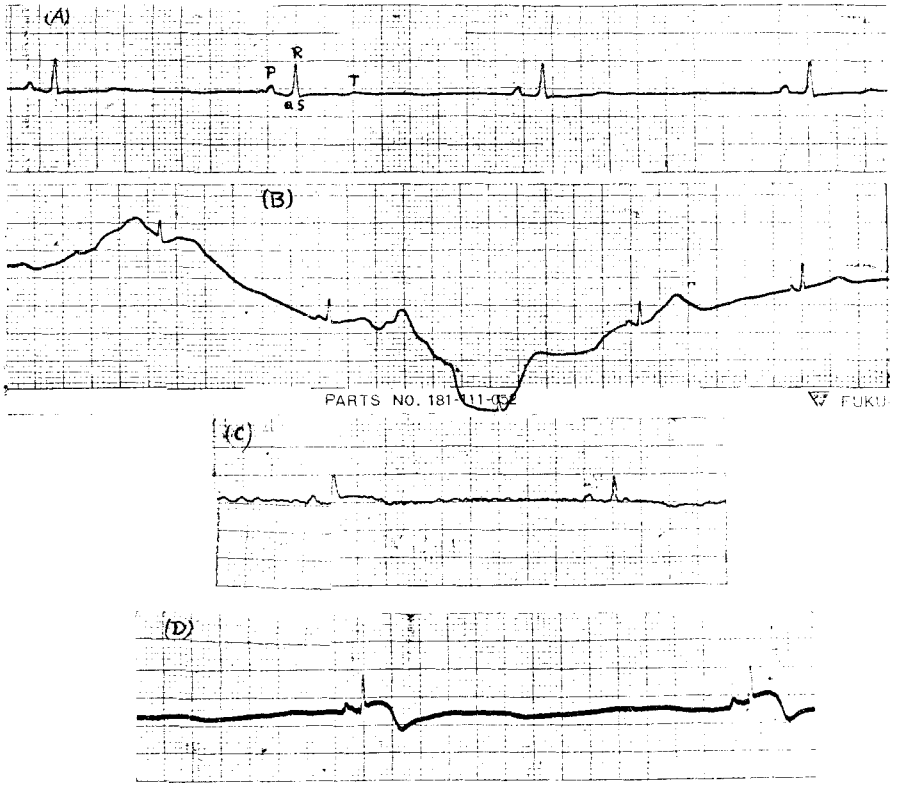


Fig.3. Changing electrogram patterns ( 1mv = 10mm ) had been recored under various conditions : (A) in a normal state , (B) after insertion of stimulated needle into belly , (C) injection of an 0.048 mg/kg adrenalin into hepatic vein , (D) after a longlasting experiment.

Table 2 Comparision of heart rate of *Cyprinus carpio* between the group living free and the group living free with a single needle stimulation.

| Free Group | | Stimulated Group | |
|---|---|---|---|
| Heart Rate * ( per min . ) | R—R Interval ( sec. ) | Heart Rate * ( per min. ) | R—R Interval ( sec. ) |
| 30 | 1.99 | 75 | 0.80 |
| 46 | 1.31 | 55 | 1.09 |
| 41 | 1.45 | 68 | 0.88 |
| 38 | 1.58 | 71 | 0.85 |
| 36 | 1.68 | 62 | 0.96 |
| 33 | 1.82 | 74 | 0.81 |
| 35 | 1.72 | 60 | 0.99 |
| 32 | 1.86 | 71 | 0.84 |
| 39 | 1.54 | 73 | 0.82 |
| 45 | 1.32 | 64 | 0.93 |
| 28 | 2.13 | 62 | 0.96 |
| 39 | 1.54 | 70 | 0.86 |
| 35 | 1.72 | 68 | 0.88 |
| 34 | 1.77 | 72 | 0.82 |
| Average 36.5 | 1.673 | 67.5 | 0.892 |

* Heart Rate = 60 / R—R Interval. $t = 14.41, P < 0.001$

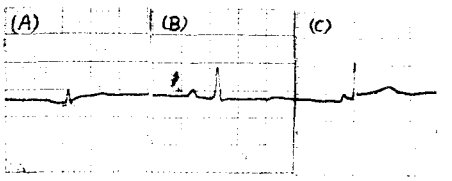


Fig.4. The voltage magnitude ( 1 mv = 10 mm ) depends on the distance between the heart and the exploring electrode: ( A ) electrode just contact with epidermis of skin , ( B ) and ( C ) needle inserting into dermis 2cm and 4 cm in depth , respectively.

## Discussion

From the result showing in Fig.2 , we conclude that there is a big difference of tracing if the indifferential electrode and exploring electrode were placed on the different parts of surface of fish heart. Apparently the most Suitable position in which a typical electrogram of *Cyprinus carpio* was taken is to place needles on surface of left ventricle. In the processes of experiment , we inserted the needle into the intact fish at the left side of the belly below the anterior margin of left pectorial fin vertically , and we got the electrocardiogram which is similar pattern to that of human in Lead II. This is the most suitable position we had found in experiment and was never indicated by other investigators( 7 , 9 , 11, 16 , 17 ). Typically , the events of electro-

gram of fish heart are P wave followed by a QRS complex and a T wave in sequence. The P wave is produced by auricular depolarization the QRS complex by ventricular depolarization, and the T wave by ventricular repolarization. In the intact fish heart, the principle of depolarization is applicable and the electrogram pattern is identical with that of other vertebrates.

From the fact of negativity at the exploring electrode produced downward deflection in the tracing we can conclude that our tracing correspond to the CF lead as usually applied in the clinic. The voltage magnitude depends on the distance between the fish heart and the exploring electrode. Bianki et al. (1) and Hirsch et al. (5) reported that the activity of fish heart did not stay under the influence nerves except vagus , while in this observation an adrenalin in 0.048 mg per kg of body weight may evoke sinus arrhythmias without changing in heart rate to an intact fish. This result shows some difference from that of others observations (2, 12). Change in heart rate during exercise may be related to the increase of sympathetic tone, the increase of catecholamine level, or to increase in venous pressure ( 2 , 12 , 17 ) , but in this experiment an increase of heart rate with an anstable base line of electrogram tracing was observed during needle stimulation.

## References


1. Bianki, V.L., and A.M. Vinnitskii, 1965. Cardiac conditioned reflexes in cerebellectomized fish. Doklady Akad. Nauk SSSR, (English translation) 164: 674-7.
2. Bloom, G., E. Ostlund, U.S. von Euler, F. Lishahko, M. Ritzen, and J. Adams-Ray 1961. Studies on catecholaminecontaining granules of specific cells in cyclostome hearts. Acta Physio. Scand. 53, suppl. 185: 1-34.
3. Bruno Kisch, Franz M. Grodel, and R. Borchardt. 1947. Exp. med. and surg., V. 925.
4. Dornesco, G.T., and V. Santa. 1963. La structure des aortes et des vaisseaux sanguins de la carpe, Anat. Anz. 113: 136-145.
5. Hirsch, E.F., M. Jellinek, and T. Cooper. 1964. Innervation of the systemstic heart of the California hagfish. Circulation Res, 14: 212-7.
6. Hoar, W.S., and D.J. Randall. 1970. Fish Physiology, Vol. 4.
7. Hoffman, B.F. and P.F. Cranefield. 1960. The electrophysiology of the heart. McGraw-Hill, New York, p 323.
8. Holeton, G, F., and D.J. Randall. 1967. The effect of hypoxia upon the partial pressure of gases in the blood and water afferent and efferent to the gill of rainbow trout. J. Exptl. Biol. 46: 317-327.
9. Kisch, B. 1968. Electrographic investigations of the heart of fish, Exptl. Med. Surg. 6: 31-62.
10. Prosser-Brown. 1962. Comparative Animal Physiology.
11. Oets, J. 1950. Electrocardiograms of fishes. Physiol. Comp. Oecol. 2: 181-186.
12. Ostlund, E. 1954. The distribution of catecholamines in low animals and their effect on the heart. Acta Physiol. Scand. 31, suppl. 112: 1-67.
13. Randall, D.J., and G. Shelton. 1963. The effect of changes in envitronmental gas concentrations on the breathing and

heart rate of a teleost fish, Comp. Biochem. Physiol. 9 : 229-239.
14. Randall, D. J., and J. C. Smith. 1967. The regulation of cardiac activity in fish in a hypoxic environment. Physiol. Zool. 40 : 104-113.
15. Randall, D. J. 1968. Functional morphology of the heart in fishes. Ameri. Zool. 8 : 179-189.
16. Remrow, V. A.. Electrocardiogram recording in long-term experiment. Techniques for the investigation fish physiology ( English translation ), Doklady Akad. Nauk SSSR.
17. Serfaty, R. Labat. 1961. Modifications electrocradiographiques chez ia carpe ( Cyprinus carpio L. ) au cours des changements de salinite. Hyorobiologia 18 : 185-191.
18. Singh, G. P. 1960. The structure of the heart of some fresh water teleosts. J. Zool. Soc. India. I : i-26.
19. Wilber, C. G. 1961. Some physiologic characteristics of the heart of the toadfish Opsanus tan. Chesapeake Sci. 2 : 72-75.

## 摘　要

自由生活於實驗魚箱中之台灣產台灣黑色鯉魚50尾，被用以研究改進其心電圖記錄方法。將導電極垂直插入右胸鰭前下方，而將游移導電極插於魚體背面左側鰓裂上緣時，所得之心電圖最為標準，且與人體心電圖第II肢導之圖型相似。本試驗結果顯示鯉魚之QRS 最長不超過0.06秒；心跳速率平均為36.5 次每分鐘，當以針刺激時心跳急速增加，平均增加一倍左右；低濃度之腎上腺素處理可引起實性不整脈現象；在缺氧情形下心跳變慢或停止跳動。