Table 1. Distribution of radioactivity within acetone extracts of rabbit liver homogenates incubated with $NaHC^{14}O_3$, 0.47 gm tissue was incubated in 1 ml modified (*5*) Krebs ringer solution containing 0.005 mc of the isotope; cts means "counts," where the counter efficiency is 2 percent.

Solute	Rf*	Time of incubation (min)									
		3		5		10		20		30	
		(cts/min†	%)	(cts/min	%)	(cts/min	%)	(cts/min	%)	(cts/min	%)
Compound insoluble in amyl alcohol-chloroform	0	1562	39.0	1632	38.1	3264	70.6	4224	81.6	5990	77.9
Malic acid	0.38	1907	47.4	2112	49.2	1088	23.5	819	15.8	1427	18.6
Succinic and lactic acids	0.75	544	13.6	544	12.7	275	5.9	134	2.6	275	3.5
Total activity of labeled compounds		4013		4288		4627		5177		7692	

* Ether-acetic acid-water (13-3-1) was the developing solvent for the paper chromatograms.
† Approximately one-twentieth of the total extract of the liver was applied in each case.

label into the amyl alcohol-soluble compound was not limited to an incubation time of 10 min exclusively. The percentages of the total fixation into malate at 3 and 5 min exceeded those at 10, 20, and 30 min. Since the chemical concentration of the malate did not change, these percentages mirror the changes in specific activity. On the other hand, the abundance of the label in the insoluble residue was lower at 3 and 5 min and greater at 30 min. In butanol-acetic acid-water (4-1-5), the insoluble residue moved on paper as a single spot (Rf 0.2), which gave a positive test for phosphate with acid molybdate, benzidine, and sodium acetate (*8*). When the eluted spot from butanol-acetic acid-water was hydrolyzed in HCl and rechromatographed, it was not found to be a hexose or triose. The rechromatographed spot, tested with diphenylamine, showed that difference (*9*) between the optical density D at 660 and 580 mμ ($D_{660} - D_{580} = D_{400}$) that is characteristic of glycolaldehyde. However, the spectral absorption between 500 and 700 mμ was not identical to that of the product from the known glycolaldehyde, even though the mobility of the compound on paper in the butanol-acetic acid-water system was like that of the authentic glycolaldehyde.

Such relative incorporation into the organic acids and the insoluble compound at the several times of incubation shown here distinguishes carbon dioxide fixation in the liver of the rabbit from similar findings in other species. If the utilization of the label by the organic acids and the compound insoluble in amyl alcohol-chloroform occurs by independent mechanisms and if the insoluble compound is glycolaldehyde phosphate, the data could be explained by current views concerning the path of carbon in animal cells (*10*). By such views it would be presumed that the carbon was first fixed into a hexose, the precursor of sedoheptulose which later cleaved between carbons 2 and 3 to produce the labeled glycolaldehyde.

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Activity in Electrogenic Organs of Knifefishes

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The knifefishes, which comprise the family Gymnotidae, and inhabit fresh tropical waters of Central and South America, are close relatives of the electric eel, *Electrophorus electricus*. They possess structures that resemble the electric organ of the eel, but identification of these with functional electric organs has been doubted (*1*). Only a single report (*2*) mentions electric activity in *Gymnotus carapo*.

Three species of knifefishes examined in a preliminary survey in this laboratory have all proved to be electrogenic. These are *Eigenmannia virescens*, *Gymnorhamphichthys hypostomus*, and *G. carapo*. Unlike the eel, which emits single or short bursts of pulses of high intensity, up to 600 v and 1 amp, these fish emit low intensity pulses (Fig. 1) continuously and with remarkable regularity (Fig. 2). In this they resemble the Mormyridae of Africa, *Gymnarchus* (*2*), *Mormyrops boulengeri* (*2*), and *Mormyrus kannume* (*3*).

The responses were recorded from intact fishes swimming freely or lying on the inclined floor of a tank with only the head immersed. The electrodes were wires, spaced 5 mm to several centimeters apart, insulated except at their tips, and placed near the swimming fish or alongside the quiescent ones. Despite shunting by the water, the responses, recorded oscillographically, were 10 to 300 mv in amplitude. The magnitudes preclude the possibility that the activity derives from muscles, since only electric organs are known to have in their cells the specific adaptation that permits series addition of the emf's generated by the responses of the individual cells (*4, 5*).

At 27°C the fish emitted discharges at rates of 300 (*E. virescens*), 100 (*G. hypostomus*) or 65 per second (*G. carapo*). The variations in frequency from time to time were only 10 to 20 percent. When the entire fish, or only its head was cooled, the frequency of the discharges decreased (Fig. 2). In all three species the change with temperature had a Q_{10} of 1.5 (Fig. 3).

The decrease in frequency produced by cooling only the head indicates that the discharges are centrally controlled, probably by the brain. The identical Q_{10} for all three species indicates that the control mechanism is probably the same in all. The forms of the discharges, shown in Figs. 1 and 2, and their changes with temperature cannot be evaluated from these experiments. The activity was recorded from intact fish, 10 to 30 cm long, having different geometries of electric organs, with different electrode spacings and various orientations of the fish toward the electrodes.

The significance to their economy of the rhythmically pulsatile discharges continuously emitted by the Mormyridae and knifefishes is unknown. When quiescent, the eel produces no detectable electric activity. It has been reported (*6, 7*) that when cruising in large tanks eels emit low voltage discharges at about 50 per second. The suggestion has been made (*6*) that these discharges serve to orient the fish with regard to obstacles. Were the rhythmic electric activity of knifefishes and Mormyridae to subserve this function, highly specialized, as yet unknown, sense organs might be required. The recognition of distortions, caused by solid objects, of the potential field produced in the water by the discharges would demand extremely sensitive, highly differential electric detectors.

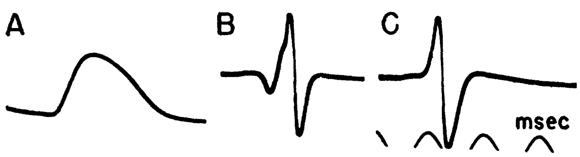

Fig. 1. Individual pulses from the series continuously emitted by three species of knifefishes. The forms changed with orientation of the fish to the electrodes and with electrode spacings. The amplitudes also depended on the geometry of the recording conditions. (*A*) *E. virescens*, (*B*) *G. carapo*, (*C*) *G. hypostomus*. Time in milliseconds.

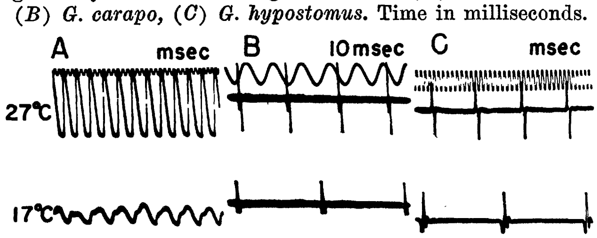

Fig. 2. Dependence of the frequency of the discharges on temperature. *A, B, C,* as in Fig. 1. Only the head of *G. hypostomus* (*C*) was cooled in this experiment.

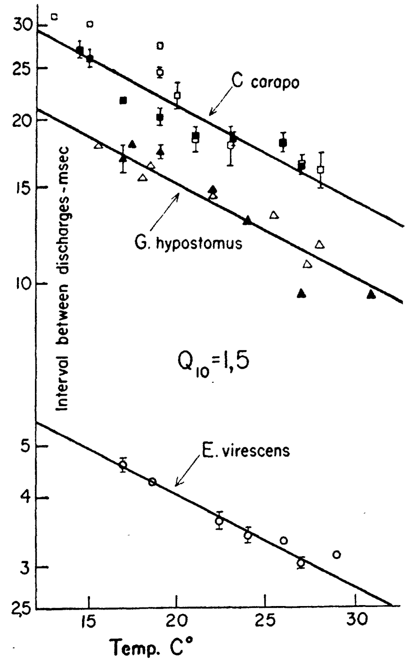

Fig. 3. Temperature coefficients of the discharges. Filled symbols represent duplicate experiments. The extent of variations in frequency is shown by the lines though averaged values.

The cells of the electric organs of the knifefishes, in their structure and organization, appear to resemble those of the organs in the electric eel (*8*). Recent studies of unitary activity in the latter (*4, 5, 9, 10*) and in *Raia clavata* (*11*) have disclosed important features belonging to the general properties of bioelectric generators as well as special adaptations that make for electric organs. The existence of electrogenic properties in all three knifefishes examined in this survey indicates that others of the approximately 50 species in this family might also possess these. Some are relatively easily obtainable tropical fishes. This offers additional material for investigations on electric organs as well as the possibility for further insight into problems of bioelectric activity.

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