stimuli of the laryngo-pharyngeal region is presented, the fibre activity demonstrates a non-repeated pattern in successive respiratory phases. Figure D indicates the pattern of the same unit as in C but during stimulation of the central end of the cut glossopharyngeal nerve to evoke swallowing. This non-repeated pattern resembles the activity of most inframandibular single motor units active during swallowing or that of the genioglossus motor units active in both inspiration and swallowing[11].

These results suggest that the motoneurons of the nucleus ambiguus, activated by the brain stem respiratory interneurons, can be synaptically excited in a semi-stereotyped sequence. Such synaptic excitation is not evident in cranial motoneuron activity in swallowing, and is lost with the interaction of sensory stimuli from the primary nerve (in the cat) evoking swallowing with the synaptic drive of the respiratory pathway on motoneurons innervating the laryngeal musculature.

Résumé. L'interaction des données sensorielles pharyngiennes provenant du nerf glossopharyngien et des influences synaptiques respiratoires du tronc cérébral sur les motoneurones crâniens du noyau ambigu, indique que la caractéristique de décharge répétée des fibres motrices du nerf récurrent durant la respiration devient non-stéréotypée durant l'alternance de la déglutition et de l'inspiration.

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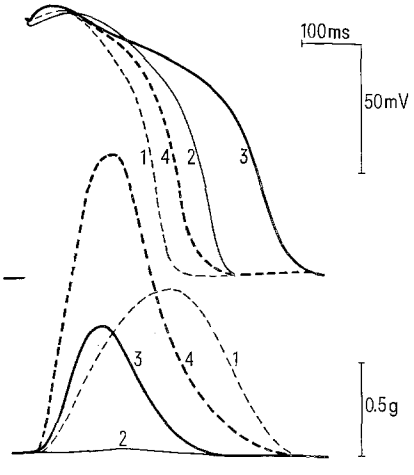
Effect of Epinephrine on the Duration of Action Potential of Papillary Muscles

The duration of cardiac action potentials (AP), namely ventricular, is variable within a relatively broad range of values. It generally abbreviates under those influences, which at constant muscle length increase the rate of tension development; at increased Ca concentration in the medium, at increased frequency of stimulation, during adaptation to rapidly decreased temperature and after artificially prolonged depolarization in sucrose gap experiments[1]. It has been postulated that the abbreviation of AP might reflect a feed-back effect of increased intracellular Ca concentration, which is the common denominator of the above inotropic interventions. The effect of epinephrine, however, does not match this scheme. It increases the Ca influx[2,3] and rate of Ca movements across the sarcotubular membranes[4]; accordingly it exerts a strong positive inotropic effect but is without an appreciable influence on the AP duration[5]. The present experiments were undertaken to explain this discrepancy.



Transmembrane action potentials (upper traces) and corresponding isometric contractions (lower traces) redrawn from a representative experiment on cat papillary muscle. Stimulation frequency 30 min, temperature 31 °C. 1. Control in normal Tyrode solution; 2. after 20 min in Ca-free Tyrode; 3. 1 min after addition of 10^{-6} *M* epinephrine to Ca-free Tyrode; 4. 1 min after subsequent addition of 1.8 m*M* Ca.

Material and method. The experiments were performed on 8 papillary muscles of cats and confirmed on 22 papillary muscles of guinea-pigs, and on 5 dog trabeculae from the right ventricle. The animals were sacrificed under the urethane anesthesia, hearts were rapidly removed and the preparation was placed into oxygenated Tyrode solution (Na 149 m*M*; K 5.4 m*M*; Ca 1.8 m*M*; Cl 145 m*M*). The temperature was held constant at 31 °C. Preparations were stimulated at 4 sec intervals unless otherwise stated. Isometric contractions (electromechanical transducer RCA 5734) and transmembrane potentials (glass microelectrodes of 5–15 MΩ) were recorded from oscilloscope tracings. Epinephrine was administered in concentration 6×10^{-6} *M*. Preparations in which epinephrine elicited spontaneous activity were discarded.

Results and discussion. Under control conditions, epinephrine caused a marked positive inotropic effect and only insignificant changes of AP duration, measured at any level of repolarization. However, if the rate of stimulation was decreased to 7.5 or 4/min, epinephrine always tended slightly to prolong the AP. On the other hand, at stimulation frequency of 60 or 90/min, a small shortening of AP usually followed. Shortening of AP due to epinephrine was also observed in high-Ca Tyrode (5.4 m*M*) and prolongation in low-Ca Tyrode (0.6 m*M*).

The bulk of experiments were performed under electromechanical uncoupling in Ca-free Tyrode (Figure). Epinephrine unambiguously and markedly prolongs AP duration under these conditions. The effect is well marked after 1 min of exposure and usually reaches peak value after 2 min. The extent of this change individually varies

[1] P. BRAVENÝ and J. ŠUMBERA, Pflügers Arch. ges. Physiol. *319*, 36 (1970).

[2] H. REUTER, Pflügers Arch. ges. Physiol. *278*, 357 (1966).

[3] G. VASSORT, O. ROUGIER, D. GARNIER, M. P. SAUVIAT, E. CORABŒUF and Y. M. GARGOUIL, Pflügers Arch. ges. Physiol. *309*, 70 (1969).

[4] M. MORAD and E. L. ROLETT, J. Physiol., Lond. *224*, 537 (1972).

[5] B. F. HOFFMAN and P. F. CRANEFIELD, *Electrophysiology of the Heart* (McGraw-Hill, New York 1960).

from 30 to 100% of the control, probably in dependence on the metabolic state of the preparation. Even larger effect is regularly observed after wash-out and repeated application of epinephrine. It is to be noticed that the contractility reappears after epinephrine in Ca-free Tyrode. Time to peak tension is significantly shorter than the plateau phase. This dissociation is particularly marked in cats. It is assumed that the mechanical response originates from additional liberation of Ca from the reticular stores. Comparable effects were obtained after the administration of norepinephrine and isoproterenol in the same dose. The reaction to all 3 catecholamines was entirely prevented by β-adrenolytic agent propranolol (Inderal, concentration 10× exceeding that of epinephrine).

If the missing Ca is added to the solution at the period of fully developed effect of epinephrine, immediately a second contraction appears during the terminal phase of AP (not shown in the Figure), then the initial mechanical response rapidly increases and subsequently the AP shortens to the vicinity of the control values.

From these experiments it can be deduced that the reported absence of influence of epinephrine on AP duration might result from its 2 opposing effects: the first tends to prolong the time of repolarization; the second is indirect and appears to be related to increased intracellular concentration of Ca. At normal Ca concentration and medium rates of driving, both effects are in an approximate equilibrium and counterbalance each other.

Zusammenfassung. Im Gegensatz zur Kontrollbedingung (Tyrodelösung 1.8 m*M* Ca, 31°C, Reizfrequenz 30/min) ruft Adrenalin $6 \times 10^{-6}M$ im Ca-freien Milieu eine significante Verlängerung der Aktionspotenziale hervor. Die Zugabe von Ca^{2+} kehrt die Aktionspotenzialdauer mit voller Entwicklung der positiv inotropen Wirkung zu Ausgangswerten zurück.

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Respiratory Properties of the Blood of the Thornback Ray

Oxygen dissociation properties of whole blood of several elasmobranchs have been investigated, but few recent studies have been concerned with skates or rays. Arterial blood samples can be obtained via indwelling catheters without disturbing the resting fish. The average pH of arterial blood in vivo is 7.7 at 15°C. P_{O_2} is low (about 58 mm Hg) but higher values were obtained during hyperventilation, at low temperatures, and from anaemic fish.

Dissociation curves (Figure 1) were determined using a mixing method. Because of progressive changes in the P_{O_2} of such mixtures, each sample was used for no more than two points on the curves. The oxygen capacity (3.5 ml/100 ml blood, l.c. = 0.9) is relatively low. The sigmoid dissociation curve (Hill exponent n = 2.5, l.c. = 0.3) has a P_{50} of 30.2 mm Hg (l.c. = 2.8) at the physiological pH of 7.7 at 15°C. As in *Raia oscillata*[1] a definite Bohr shift (Δ log P_{50}/Δ pH = -0.25 ± 0.03) is found (Figure 1), but it is less than that of most fishes and of human blood. There is also evidence for a Haldane effect (Figure 2) which contrasts with results obtained on dogfish blood[2], but is consistent with the presence of a Bohr effect which theoretically requires a Haldane effect of similar magnitude[3].

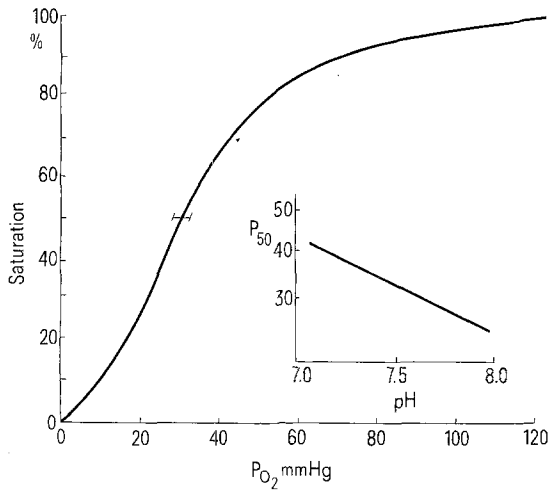

Fig. 1. *Raia clavata* O_2 dissociation curve of whole blood at pH 7·7, 15°C (average of 15 individuals). Horizontal bar indicates 95% confidence limits of P_{50}. Insert shows the Bohr effect.

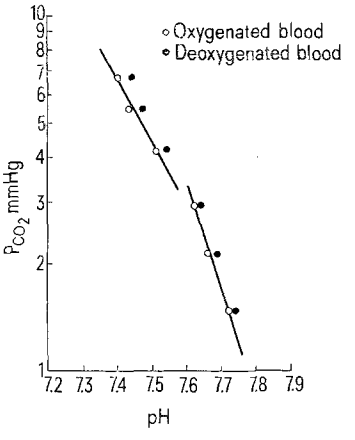

Fig. 2. *R. clavata* Log P_{CO_2}-pH diagram of whole blood. Each point represents a mean of 4–6 measurements. Fresh blood used for equilibration at each P_{CO_2}. Bicarbonate concentration calculated from $pK^- = 6.08$ at pH 6.75 and 15°C, $\alpha = 0.053$[5], was about 3.4 m*M*/l at pH 7.7. Buffer capacity (Δ HCO_3^-/l/Δ pH) was approximately 10 slykes between pH 7.4 and 7.7.

[1] D. B. Dill, H. T. Edwards and M. Florkin, Biol. bull. mar. biol. Lab. Woods Hole, *62*, 23–36 (1932).

[2] J. Piiper and D. Baumgarten-Schumann, Respir. Physiol. *5*, 326–337 (1968).

[3] E. Antonini, Physiol. Rev. *45*, 123–170 (1965).