Effect of Change in Length of Day on the Insulin Sensitivity of the Rat Heart

Galactose, a stereoisomer of glucose which is not metabolized by peripheral tissues[1,2], is transported in the isolated perfused rat heart by an insulin-sensitive carrier mechanism[2]. The effect of insulin, which is to increase markedly the rate of movement of the sugar across the muscle cell membrane, is most clearly demonstrated in the efflux of the sugar from the tissue. Hearts loaded with galactose by perfusion for 20 min. with a Krebs–bicarbonate medium containing the hexose (1 gm./100 ml.) are transferred to a sugar-free perfusate, and the effluent collected in a timed sample. The fractional fall in the heart galactose content during the fourth minute after transfer is used as a measure of efflux-rate. It has been shown[3] that the dose-response curves of rate of galactose efflux against insulin concentration show a marked seasonal variation; the sensitivity being greatest in summer and least in winter (Fig. 1). The dose-response curves are Michaelis–Menten in form; and the change with season suggests the presence of a competitive inhibitor of insulin during the winter months.

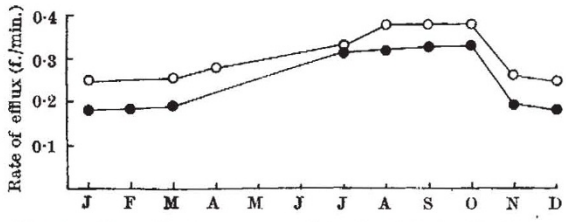

Fig. 1. Change in the response of the heart to insulin during the course of the year. The response, which is measured as the rate of efflux of galactose (the fraction of the heart content emerging in the fourth minute), is recorded for two concentrations of insulin; ○, 1·0 mμ/ml.; ●, 0·5 mμ/ml.

It was found that hearts removed from rats maintained during winter with a 12-hr. day of artificial light gave the same response as rats kept under natural lighting conditions in summer; the respective figures for the fractional fall in the heart galactose content with 1 mμ/ml. of insulin were: 0·36 ± 0·02 (5) during the winter period with twelve hours light, 0·38 ± 0·1 (8) during summer and 0·25 ± 0·02 (8) during winter with natural day-lengths. The sharp fall in insulin sensitivity in the early autumn (Fig. 1) suggested, therefore, that the presence of the inhibitor might be related to the rapid shortening of the day at this time of the year.

The following experiment was carried out in winter (January–February) in a constant-temperature environment to test this supposition. A number of rats which had been maintained on a constant day-length of 12 hr. of artificial light were divided randomly into two groups. The control group continued on the constant day-length of 12 hr. The day-length of the experimental animals, also maintained with artificial light, was shortened by daily decrements for six weeks so that the natural decrement in day-length corresponding to that of September 26–November 15 (lat. 52° N.) was closely simulated. At the end of this period the rats were killed and the response of the hearts to 0·5 mμ/ml. of insulin determined. The rates of galactose efflux (fraction/4th min.) were 0·31 ± 0·02 (6) and 0·21 ± 0·02 (6) for the controls and experimentals, respectively. Thus the effect of decreasing day-length can be induced experimentally; the effects of maintaining the relatively constant winter day-length and of increasing day-length, however, have yet to be investigated.

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Electrical and Mechanical Activity of the Chick Amnion

A physiological study of conduction and excitation in the smooth muscle of the chick amnion is of interest as this structure is devoid of nervous elements.

Prosser and Rafferty[1] have recorded conducted action potentials from the musculature of the chick amnion with surface electrodes and have adduced this as evidence for intercellular conduction in smooth muscle. A more satisfactory method of recording the action potentials has been developed by using the sucrose gap technique, first described by Stämpfli[2], in which the extracellular fluid of part of the preparation is replaced by a non-conducting sucrose solution. This greatly reduces the conduction through the extracellular fluid and produces monophasic action potentials, the shape of which can be more closely studied.

Strips of chick amnion were dissected from the dorsal surface of 6–14 day embryos and mounted in a sucrose gap apparatus, one end being connected to a mechano-electronic transducer. The apparatus was similar to that described by Bülbring and Burnstock[3] for the guinea pig tænia coli. Hanks's balanced salt solution was used as the physiological saline solution throughout this work, and the temperature of the preparation maintained at 38° C. The flow-rate was approximately 2 ml./min. Changes in membrane potential and in isometric tension of the strip have been recorded photographically from a dual beam oscilloscope. It has been confirmed that conducted action potentials occur in the chick amnion and that these are correlated with changes in tension.

The chick amnion has autorhythmicity and Fig. 1 shows parts of a record from a spontaneously active preparation. The action potentials are of long duration, some 2–5 sec., and are preceded by a period of slow depolarization, the so-called prepotential. There is a rapidly rising depolarization phase, a plateau and a slower phase of repolarization, often followed by a small hyperpolarization. The plateaux show small undulations and are possibly composed of fused spikes, due to the asynchronous firing of many units. However, the ureters of the rat and guinea pig show such plateaux[4], which persist even with micro-electrode recording (Burnstock, G., personal communication).

Fig. 1. 14-day amniotic membrane strip showing spontaneous rhythm. Electrical activity is shown on the top trace and mechanical activity below