by centrifugation of homogenates at 120,000 × *g.* for 30 minutes, when added to washed mitochondria, restored the activity to essentially the level originally obtained in the crude system.

Both the crude and partially resolved systems require the addition of diphosphopyridine nucleotide (DPN) and nicotinamide. Triphosphopyridine nucleotide (TPN) does not replace the DPN requirement. The over-all oxidation process shows a partial dependence on the presence of adenylic acid (AMP) although this phenomenon may be related to the stabilizing effect of adenylic acid and adenosinediphosphate on the general metabolic integrity of mitochondria.[5]

As shown in Table I, dialysis of the soluble fraction of the system does not lead to a significant loss in activity, nor can this fraction be replaced by a concentrated, boiled extract of whole liver or liver fractions. The inactivity of either the mitochondrial or the soluble fractions alone, and the demonstration of a considerable lag phase in the appearance of $C^{14}O_2$ suggests, as one possibility, the accumulation of an intermediary compound derived from the side chain carbon atoms which is subsequently oxidized by the terminal oxidizing systems of the mitochondrial elements.

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RECEIVED JANUARY 23, 1953

ENZYMATIC CLEAVAGE OF THE CITROVORUM FACTOR

Sir:

In our studies with soluble enzyme preparations which liberate bound forms of folic acid from liver, we observed that citrovorum factor (CF) added to such preparations disappeared at a rapid rate. We now have obtained from horse liver a protein fraction which, in the presence of *l*-glutamic acid, effectively destroys CF.

The protein fraction was obtained as the 30% saturated (0°) ammonium sulfate precipitate from a cold water extract (0°) of horse liver.

The influence of *l*-glutamic acid on the rate of inactivation of CF by the liver fraction is shown by the data in Table I. The loss of CF activity as measured by both *Leuconostoc citrovorum* and *Streptococcus faecalis* R, is paralleled by a rise in arylamines indicating a cleavage of the pteridine moiety from the *p*-aminobenzoylglutamic acid residue.

TABLE I

RECOVERY OF CF AFTER INCUBATION WITH LIVER PROTEIN FRACTION

Incubated at 37° for 2 hr. in 0.08 *M* Na_2HPO_4; volume, 7 ml.; initial CF = 56 γ.

L-Glutamic acid, *M*	None	0.001	0.002	0.004	0.0075	0.01
CF, γ	51.0	36.8	31.2	26.6	24.2	23.0

The role of *l*-glutamic acid appears to be specific. Other amino acids including *l*-glutamine and also known metabolic products of *l*-glutamic acid do not replace *l*-glutamic acid in this system. It is significant that *p*-aminobenzoic acid inhibits the reaction (31% inhibition with 0.01 *M* concentration of *l*-glutamic and *p*-aminobenzoic acids). While CF is attacked readily by the protein fraction in the presence of *l*-glutamic acid, neither pteroylglutamic acid nor its N-10-formyl derivative is affected.

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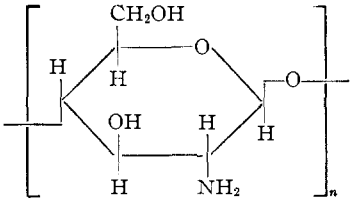
RECEIVED FEBRUARY 20, 1953

DIRECT EVIDENCE OF THE INFLUENCE OF SULFAMIC ACID LINKAGES ON THE ACTIVITY OF HEPARIN-LIKE ANTICOAGULANTS

Sir:

Heparin, the naturally occurring glucosamine-glucuronic acid polysaccharide polysulfate, is characterized by its high anticoagulant activity (U.S.P. Heparin is defined as having not less than 100 International Units per mg.) and by its essentially nontoxic nature (mouse intravenous LD_{50} = 1500–2000 mg./kg.[1]). Extensive work by numerous investigators has indicated that the activity of heparin is dependent, among other things, upon the degree of sulfation of the molecule and recently both Jorpes[2] and Meyer[3] concluded, as earlier considered a possibility[4] and more recently affirmed[5] by Wolfrom, that the amino groups in the molecule are sulfated and demonstrated that hydrolysis of the protected amino linkages resulted in essentially complete inactivation of the material. In order to test the validity of the postulate that the presence of sulfamic acid groups is a major factor essential for the high activity and presumably for the low toxicity of heparin, and also because the stated conclusions were based largely upon indirect evidence, we undertook to obtain direct evidence of the contribution of sulfamic acid linkages to the anticoagulant activity of polysaccharide polysulfate esters of the heparin type.

In this work the polyglucosamine, chitosan



was used as a model substance in sulfation experiments designed for the preparation of products in which the amino and hydroxyl groups were sulfated to varying degrees. Some of the data obtained on some of these products are given in Table I.

Thus, for the first time, there are data which indicate a correlation in agreement with the hypothesis

(1) J. Seifter and A. J. Begany, *Am. J. Med. Sci.*, **216**, 234 (1948).
(2) J. E. Jorpes, H. Boström and V. Mutt, *J. Biol. Chem.*, **183**, 607 (1950).
(3) K. H. Meyer and D. E. Schwartz, *Helv. Chim. Acta*, **33**, 1651 (1950).
(4) M. L. Wolfrom and W. H. McNeely, THIS JOURNAL, **67**, 748 (1945).
(5) M. L. Wolfrom, R. Montgomery, J. V. Karabinos and P. Rathgeb, *ibid.*, **72**, 5796 (1950).