out that strains of pneumococci exist which can grow under anaerobic conditions. A grant made to Dr. S. Weinstein, of the University of Toronto, led to the publication of a paper on the purification and assay of one of the sex hormones obtained from human urine during pregnancy. The grant to Dr. J. K. W. Ferguson, of the University of Western Ontario, for apparatus enabled him to complete a study of the carbamic compounds which are so important in the transport of carbon dioxide in the blood stream; a study of very considerable physiological importance. A small grant was made to Dr. M. J. Wilson, of the University of Toronto.

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SPECIAL ARTICLES

NEW RECORDS IN HUMAN POWER

FIVE young men of international renown in distance running have been examined recently in this laboratory. In the group were: Lash, who within the past year has established new world's records in the 2-mile run, indoors and out; Cunningham, who holds world's records in the mile run, both indoors and out; San Romani and Venzke, milers on the U. S. Olympic team, who, with the fifth man, Fenske, have run the mile in near world's record time. All the men were in good running form at the time of the experiments.

Observations were made on the runners during rest and in four grades of work. The work of the first three grades was on a motor-driven treadmill: (1) a 15-minute walk at 5.6 kilometers per hour up an 8.6 per cent. grade; (2) a 5-minute run at 11.3 k.p.h. on the same grade; (3) a 5-minute run at 18.7 k.p.h. on a 4.0 per cent. grade. The fourth form of work was actual racing in an indoor track meet on February 13; five minutes after each man's race, venous blood was drawn for analyses.

The blood of these runners is like that of untrained man. The alkaline reserve, defined as the vols. per cent. of CO_2 in oxygenated blood at $pCO_2 = 40$ mm, averaged 48.1 as compared with 48.0 in a group of untrained men. The concentration of hemoglobin in blood and of proteins in plasma were within the limits observed in untrained man. The oxygen-combining capacity after the races ranged from 22.5 to 24.5 vols. per cent. in Cunningham, Venzke and Lash. The respective increases in the races were 7.6, 8.2 and 13.2 per cent. Each observed increase in oxygen capacity closely corresponds to the increase calculated from the observed change in plasma protein on the assumption that no protein leaves the circulation. The plasma chloride in rest and after races was normal, except for Lash, whose chloride shifted from 106.1 m.-eq. per liter in resting plasma to 99.0 after the race in which he broke the world's record for the 2-mile run. The races caused blood lactic acid to rise from 10, 16 and 9 mgm per cent. in rest to 116, 134 and 150, respectively, in Lash, Cunningham and Venzke.

The ratio $\frac{\text{residual air}}{\text{total lung volume}}$ averages 0.288 in the 5 runners and 0.285 in 11 non-athletic young men measured in this laboratory. The average vital capacities in the 2 groups are 5.36 and 4.74 liters, respectively. Expressed in liters per m of body height, the averages are 3.03 liters, ranging from 2.85 to 3.52, in the runners, and in the other group 2.73, ranging from 2.27 to 3.05. Hurtado[1] found an average of 2.72 liters per meter of height in 50 young men.

The maximum ventilation of San Romani, Venzke and Lash, the only runners who went through the hardest grade of work in the laboratory, averaged 113 liters per minute, as compared to 98 liters per minute of 99 other subjects in maximum work. The ratio $\frac{\text{tidal air}}{\text{vital capacity}}$ is practically the same in both groups, averaging 0.458 and 0.464, respectively. The greater ventilation in the runners was due principally to their average respiratory rate of 48, the rate of the untrained being 44. The tidal air of the runners was 2.38 liters with the untrained 2.25 liters. For a given oxygen intake the runners' ventilation was about 12 per cent. less than that of the other subjects.

In the walk at 5.6 k.p.h. the oxygen intake of the 5 runners averaged 1.0 liter per m^2 body surface and the blood lactic acid, 13.4 mgm per 100 cc blood; in 8 untrained young men the averages were 0.99 and 19.1. The similarity of oxygen intake means that in this sort of activity the efficiency is about equal, but the lower lactic acid level in the runners reflects their superiority of oxygen supply to tissues.

Oxygen intake and blood lactate in the harder grades of work are shown in Fig. 1. It will be noted that the runners adapted themselves quite readily to the speed by attaining relatively high oxygen intake. They kept the lactic acid at a fairly low level and finished the run with comparative ease. In this run all the untrained men were compelled to supply a considerable fraction of the energy anaerobically. Thus they accumulated more lactic acid, and only 2 were able to continue for the full 5 minutes. The measurements recorded in this run probably represent maxi-

[1] A. Hurtado and C. Boller, *Jour. Clin. Invest.*, 12: 793, 1933.

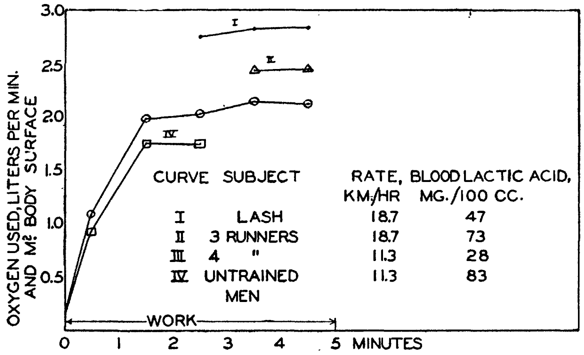

Fig. 1

mal levels of metabolism in all individuals except the runners. Skill is no doubt a factor in the easy adaptation of the runners, but since we did not measure oxygen debt we have no actual measurement of the total energy requirements of the men. When 3 of the runners ran for 5 minutes at 18.7 k.p.h., a task which brought lactic acid up to about the same level as that found in the other men in their maximal work, the runners in all cases elevated their oxygen intake even more, and in 2 of the cases probably reached their maximums. One of the most remarkable observations in the entire experiment was Lash's consumption of 4.96, 5.08 and 5.1 liters of oxygen successively in the last 3 minutes of this run and finishing with a blood lactic acid of only 47.5 mgm per cent. His highest R.Q. in this run was 0.99. In another experiment he reached an oxygen intake of 5.35 liters per minute in a run at 21.6 k.p.h. with no grade. This is approximately the same pace that he runs in his 2-mile race. If related to basal metabolism, this means that he elevated his metabolic rate to 21.4 times its basal level as compared to 14.5, the maximum of the best untrained man. This far exceeds previous records of a similar character, such as those of Henderson and Haggard[2] on Yale oarsmen, Christensen[3] on Danish cyclists and Hill[4] on Cornell runners. The high rate of oxygen intake which can be attained by these men is due largely to extremely high cardiac output, since their blood is normal in oxygen-carrying capacity.

The heart rates were recorded continuously throughout work and recovery by a cardiotachometer. The 5 runners performed the walk with an average pulse rate of 111 per minute, while the other men averaged 134. The average recovery is much quicker in the runners, dropping 34 beats to 77 in the first 30 seconds after stopping work, while at the same time in recovery the other group dropped 19 beats to 115. The next grade of work was hard enough to cause the untrained men to reach their maximum heart rates; they averaged 190, while the 4 runners who went through this run reached an average of 171. The hard work (not attempted by the untrained men) brought the blood lactic acid of the runners up to an average of 73 mgm per cent. and the average heart rate to 189, approximately the maximum of untrained man. The average heart rate for each group after the hardest work attempted is given in Fig. 2. Recovery took place at

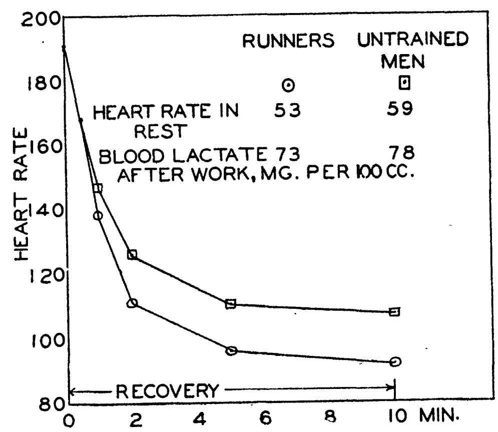

Fig. 2

the same rate in the first half-minute, after which the runners' pulse fell more rapidly.

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[2] Y. Henderson and H. W. Haggard, *Am. Jour. Physiol.*, 72: 264, 1925.

[3] E. H. Christensen, *Arbeitsphysiol.*, 5: 463, 1931.

[4] A. V. Hill, "Muscular Movement in Man," McGraw-Hill, 1927.

THE DIFFERENTIATION OF PANCREATIC TRYPSINS ON THE BASIS OF THEIR SPECIFICITIES

Pancreatic juice contains at least three enzymes (trypsin, chymotrypsin, heterotrypsin[1]) which are capable of degrading genuine proteins. Synthetic substrates have been obtained recently for each of these enzymes. Thus, chymotrypsin has been found to digest simple derivatives of tyrosine and phenylalanine such as carbobenzoxy-*l*-tyrosylglycine amide and carbobenzoxyglycyl-*l*-phenylalanylglycine amide.[1] The existence of heterotrypsin was discovered because of its ability to split benzoylglycyl-*l*-lysine amide. It has now been found that crystalline trypsin readily hydrolyzes α-benzoyl-*l*-arginine amide.

The accessibility of synthetic substrates, the structure of which may be modified almost at will, makes it possible to perform comparative studies of the specificities of the various trypsins. The following table indicates the wide differences in chemical speci-

[1] M. Bergmann and J. S. Fruton, *Jour. Biol. Chem.*, April, 1937.